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2017 Coastal Master Plan

Appendix D: Planning Tool Report

Report: Version II

Date: December 2016

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Coastal Protection and Restoration Authority

This document was prepared in support of the 2017 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every five years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

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Executive Summary

Motivation

Coastal Louisiana faces long-term sustainability challenges due to severe coastal land loss and increasing flood risk. For more than four decades, national and state government agencies, state and local organizations, corporations, and citizen's groups have invested significant resources in mostly local-scale ecosystem restoration and levee protection. The continuing land loss – at a rate of about 17 square miles annually (Couvillion et al., 2011) – and tremendous impacts from the 2005 hurricanes reemphasized that more action was required and that to be effective it would need to be coordinated as part of a comprehensive plan.

Following the devastating 2005 hurricane season, Louisiana released its 2007 Comprehensive Master Plan (CPRA, 2007). The 2012 Coastal Master Plan (CPRA, 2012) built on the 2007 Coastal Master Plan and introduced a new planning framework and Planning Tool to formulate a 50-year, $50 billion investment plan.

For the 2017 Coastal Master Plan, CPRA updated its 50-year estimates of coastal conditions reflecting recently implemented projects and improved data and modeling. An updated Planning Tool re-evaluated the projects selected for the 2012 Coastal Master Plan along with new projects proposed by stakeholders through a structured process completed in 2014. The updated Planning Tool also was used to help formulate and evaluate a more refined set of nonstructural risk reduction projects. Lastly, the Planning Tool was used in an iterative process to define alternatives—sets of risk reduction and restoration projects designed to address CPRA coast wide objectives. The final alternatives then provided the basis for the draft master plan.

CPRA Planning Tool

The CPRA planning framework combines two sets of analytic capabilities: integrated models of the coastal system and a planning tool. Together, they are used to iteratively support the development of the 2017 Coastal Master Plan. Figure 1 illustrates the framework.

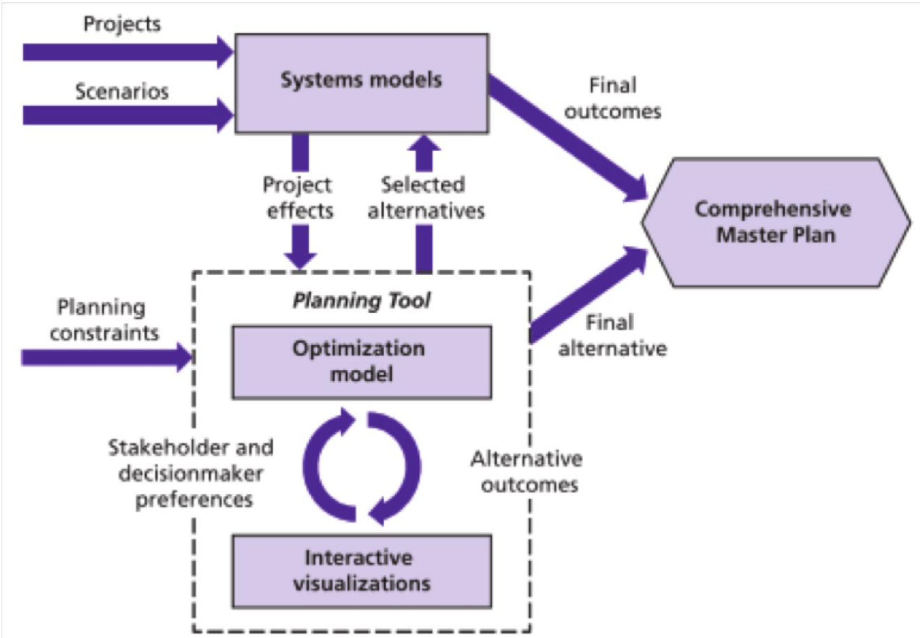

Figure 1: CPRA Analytic Framework.
Source: Groves et al. (2013).

Analysis begins by using the systems models to evaluate how proposed coastal restoration and risk reduction projects would individually affect the coast over the next 50 years relative to no action for multiple future scenarios. Additional calculations provide rough assessments of effects on navigation, communities, the oil and gas industry, fisheries, and other key assets.

The models' results serve as inputs to the Planning Tool, a computer-based decision support software system, along with planning constraints such as availability of sediment, available funding over the next five decades, and the preferences of the CPRA Board and stakeholders. The Planning Tool uses optimization to identify alternatives comprised of the projects that build the most land and reduce the most flood risk while meeting funding and other planning constraints (such as sediment and project compatibilities) and stakeholder preferences. The Planning Tool generates interactive visualizations that summarize information about individual projects and alternatives.

In the last step, the systems models evaluate together alternatives defined by the Planning Tool and informed by stakeholder and decision maker preferences. The specific projects for the final alternative from the Planning Tool and the outcomes estimates by the systems models provide key information to describe the master plan and its effects on the coast.

Planning Tool Support for the 2017 Coastal Master Plan

This approach helped bring the best available scientific information and stakeholder input to support the development of the next edition of Louisiana's coastal master plan. Specifically, the framework, systems models, and Planning Tool helped CPRA design an updated multi-billion, 50-year investment plan to address Louisiana coastal land loss and flood risk challenges, as described in the 2017 Coastal Master Plan.

To do so, they considered how the coast would change in the coming five decades with respect to a wide range of ecological and flood outcomes. These changes are impossible to predict with certainty, so the framework, models, and tool evaluated different scenarios representing different plausible futures. The systems models then evaluated hundreds of different projects individually and then as groups of projects – or alternatives. Summaries of these results and other data were provided as inputs to the Planning Tool.

The Planning Tool next developed several rounds of alternatives. In the first round, the Planning Tool was used to identify the restoration projects that would maximize coast wide land and the risk reduction projects that would maximize reduction in coast wide flood risk. Different alternatives were developed for several funding and environmental scenarios. CPRA then reviewed the results of these alternatives and chose to focus on a $50 billion funding level and to prefer projects that performed best for the least optimistic of the three environmental scenarios. In the next round of alternatives, CPRA added some additional refinements so that the Planning Tool would select projects in a way that was more consistent with CPRA objectives. For example, the Planning Tool was modified to select sediment diversion projects for implementation only in the first 30 years. The Planning Tool also evaluated the sensitivity of project selection to objectives that emphasized certain metrics such as brown shrimp habitat. These sensitivity evaluations did not lead CPRA to make any permanent adjustments to how projects were selected for the master plan.

After several rounds of alternative formulation, CPRA selected a few alternatives to be modeled as complete plans by the systems models. The Planning Tool then compared the model-estimated alternative outcomes to the alternative outcomes estimated by the Planning Tool. These comparisons showed reasonable agreement, suggesting that the Planning Tool simplifications are acceptable.

Throughout the analysis, the Planning Tool presented the results of these analyses to CPRA and stakeholders through interactive computer-based visualizations to support deliberations over the many different alternatives. This process helped CPRA define the master plan.

The Draft Master Plan is a roughly $50B package, comprised of:

- $25B of risk reduction projects
- $23.5B of restoration projects
- $1.5B barrier island program

The 2017 Coastal Master Plan significantly limits the risk by year 50 to between $4 billion and $8 billion per year, as compared to a range of $12 billion to $20 billion per year without the master plan for the medium and high environmental scenarios. The master plan also increases land, partially offsetting projected declines. For the middle scenario evaluated, the master plan avoids about 35 percent of the projected land loss without the master plan. For the higher scenario, the Master Plan avoids about 28 percent of the projected land loss without the master plan.

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List of Abbreviations

ADCIRC-SWAN	Advanced Circulation-Simulated Wave Nearshore model
AEP	Annual exceedance probability
CLARA	Coastal Louisiana Risk Assessment Model
CPRA	Coastal Protection and Restoration Authority
EAD	Expected annual damage
ESLR	Eustatic Sea Level Rise
EwE	Ecopath with Ecosim model
FWOA	Future without action
FWP	Future with project
GAMS	General Algebraic Modeling System
GIS	Geographic information system
HSIs	Habitat Suitability Indices
ICM	Integrated Compartment Model
IPET	Interagency Performance Evaluation Task Force
LMI	Low-to-Moderate Income
MCDA	Multi-Criterion Decision Analysis
MIP	Mixed-integer programming
NRC	National Research Council
RDM	Robust Decision Making

1.0 Introduction

Coastal Louisiana faces long-term sustainability challenges due to severe coastal land loss and increasing flood risk. For more than four decades, national and state government agencies, state and local organizations, corporations, and citizen's groups have invested significant resources in mostly local-scale ecosystem restoration and levee protection. The continuing land loss – at a rate of about 17 square miles annually (Couvillion et al., 2011) – and tremendous impacts from the 2005 hurricanes reemphasized that more action was required and that to be effective it would need to be coordinated as part of a comprehensive plan. Following the devastating 2005 hurricane season, Louisiana released its 2007 Comprehensive Master Plan (CPRA, 2007). The 2007 Coastal Master Plan set a new course for Louisiana by defining four high-level objectives to guide development of a comprehensive strategy:

- Reduce economic losses from storm based flooding to residential, public, industrial, and commercial infrastructure, assuring that assets are protected, at a minimum, from a storm surge that has a 1% chance of occurring in any given year.
- Promote a sustainable coastal ecosystem by harnessing the processes of the natural system.
- Provide habitats suitable to support an array of commercial and recreational activities coast wide.
- Sustain, to the extent practicable, the unique heritage of coastal Louisiana by protecting historic properties and traditional living cultures and their ties and relationships to the natural environment.

These objectives were developed to guide the state's long-term infrastructure investments on the coast. The 2007 Coastal Master Plan did not, however, provide a quantified comparison of costs and benefits for the many proposed projects, consider a wide variety of future scenarios, or define a preferred set of projects to meet these long-term goals. The plan also considered many general project concepts, rather than specific projects with defined physical attributes and costs.

The 2012 Coastal Master Plan (CPRA, 2012) built on the 2007 Coastal Master Plan and introduced a new planning framework to formulate a 50-year, $50 billion investment plan. To guide the planning process, CPRA refined the 2007 Coastal Master plan objectives to the following five:

- Flood Protection – Reduce economic losses from storm-based flooding;
- Natural Processes – Promote a sustainable ecosystem by harnessing the processes of the natural system;
- Coastal Habitats – Provide habitats suitable to support an array of commercial and recreational activities coast wide;
- Cultural Heritage – Sustain Louisiana's unique heritage and culture; and
- Working Coast – Support regionally and nationally important businesses and industries.

CPRA also supported the development of new systems models, to augment existing ones, and a Planning Tool to objectively evaluate and compare projects and formulate groups of projects (i.e., alternatives). CPRA used the Planning Tool in an iterative process with stakeholders to evaluate differences among various alternatives and define the final 2012 Coastal Master Plan.

CPRA is now developing the 2017 Coastal Master Plan, which builds on the 2012 Coastal Master Plan by refining project choices based on new project options, new data and models, and an updated Planning Tool.

1.1 Challenges in Formulating a Long-Term Master Plan for Louisiana

There are numerous challenges that Louisiana is addressing to develop a long-term coastal master plan.

1.1.1 Louisiana Coast Supports Diverse Communities and Natural Resources

Coastal Louisiana is a working coast. It is home to over two million people and is endowed with a large diversity of natural resources, many of which support economic and recreational activities. The dynamic deltaic coast provides vital habitat to hundreds of aquatic and terrestrial species. The coast is also home to large cities, such as New Orleans, with significant existing flood control infrastructure constructed by the federal government, and regional centers, such as Houma, that have little or none; what protection does exist is often constructed and maintained solely by local levee boards. There are also numerous rural and isolated communities. Any decision that affects a community and the environment is subject to debate over goals, priorities, and resource allocation.

1.1.2 Coastal Systems are Complex and will Change in Uncertain Ways

The coastal system is dynamic and interconnected. How it will change in the coming decades is highly uncertain. Drivers of change, such as rates of sea level rise, subsidence, and erosion; future hurricane activity; hydrologic fluctuations and trends; and future human activities are all but impossible to predict in the long run, despite our best scientific understanding of these processes. The ecosystem, species, and society's responses to these drivers thus will remain exceedingly difficult to predict. The specific effects that coastal investments in restoration or risk reduction projects could have on the coast are therefore similarly uncertain.

1.1.3 Wide Range of Approaches to Address Challenges

There are many approaches that could be taken to address these challenges, each with different costs and potential effects on the coast. Options to reduce coastal land loss include mechanical projects that move sediment to rebuild land to more process-based approaches of diverting sediment-rich floodwaters to wetlands in need of sediment nourishment. Other projects target specific areas of need, including bank stabilization, barrier island restoration, oyster barrier reef development, ridge restoration, and shoreline protection. Similarly, flood risk can be reduced by new or improved physical structures, such as levees and floodgates that are designed to block or reroute water. Nonstructural risk reduction measures, such as floodproofing or elevating structures, can reduce risk by increasing the resistance of structures to flooding. Acquisitions of property can also reduce risks by removing assets that could be damaged in a flood.

1.1.4 Hard Decisions

Louisiana faces hard decisions; there is no single solution that will solve every challenge facing the coast. Some activities and ecosystems face greater sustainability challenges than others. In some cases, decisions to focus investment in some areas and not in others will need to be made.

For the 2012 Coastal Master Plan, CPRA made a commitment to using the best available science in a transparent manner to help inform these necessary decisions. CPRA continues this commitment with the 2017 Coastal Master Plan by furthering its efforts in data collection, systems modeling, the Planning Tool, and public outreach.

1.2 CPRA Planning Framework and Tool

The 2012 Coastal Master Plan introduced a new planning framework and decision support tool called the Planning Tool to enable the state to objectively and transparently formulate a long-term plan. In this framework, a suite of systems models are used to estimate how the coastal system and associated flood risks would change over the next 50 years under different scenarios, reflecting uncertainty about key drivers, such a sea level rise. The models also estimate the effects of different restoration and risk reduction projects on a wide range of outcomes.

These models generate a tremendous amount of information relevant to the development of the master plan. The model data, planning constraints, and stakeholder preferences are input to the Planning Tool, and it is used to compare projects and formulate alternatives to support deliberations.

1.2.1 Use of Planning Tool to Support the 2012 Coastal Master Plan

The 2012 Coastal Master Plan used the Planning Tool to compare hundreds of restoration and risk reduction projects and define a 50-year, $50 billion master plan (CPRA, 2012; Groves, Sharon, & Knopman, 2012). To help arrive at this outcome, the Planning Tool helped support four sets of deliberations around the following questions:

1. **Comparison of individual risk reduction and restoration projects**: Which flood risk reduction and restoration projects are most consistent with the objectives of the 2012 Coastal Master Plan?
2. **Formulation of alternatives**: What alternatives (made up of groups of individual projects) can be implemented over a 50-year period to best achieve the objectives of the 2012 Coastal Master Plan, given constraints on funding, sediment resources, and river flow?
3. **Comparison of alternatives**: When compared across all the objectives of the 2012 Coastal Master Plan, which alternative is preferred?
4. **Evaluation of uncertainty**: How will the 2012 Coastal Master Plan perform, relative to its objectives, across several future environmental scenarios?

Specifically, CPRA first used the Planning Tool to help assess the overall benefits and costs of hundreds of proposed protection and restoration projects. CPRA next used the Planning Tool as part of an iterative participatory decision process to develop a large set of different alternatives and then identify a small set of alternatives that were considered as the foundation of the 2012 Coastal Master Plan. There is no "correct" alternative, and the Planning Tool is designed to formulate many alternatives and summarize the key differences among them. These selected alternatives were then run through the systems models again and reevaluated to better understand synergies and differences among the included projects.[1]

After discussions among CPRA management and stakeholders and iterations with the Planning Tool, CPRA defined a single alternative for the January 2012 draft of the Coastal Master Plan. The draft 2012 Coastal Master Plan was released on January 12, 2012, for public review and comment. CPRA held three all-day public meetings and more than 50 meetings with community

[1] The re-evaluation of the 2012 Coastal Master Plan using the systems models occurred after the publishing of the master plan.

groups, parish officials, legislators, and stakeholder groups. Thousands of comments were received and reviewed, and some of the underlying information on the individual projects was updated for accuracy.

Based on this stakeholder input, the Planning Tool was used again to evaluate how adjustments to the included projects and their implementation timing would change final outcomes. Based on a review of this new analysis, refinements were made and the final 2012 Coastal Master Plan was completed. The Louisiana legislature subsequently approved the final 2012 Coastal Master Plan unanimously in May 2012 (CPRA, 2012).

The following three figures summarize key decisions and final outcomes of the 2012 Coastal Master Plan. Figure 2 shows how 2012 Coastal Master Plan funding is allocated across different project types and the number of projects for each type; 109 projects plus the nonstructural program are included in the final alternative. Notably, about 20% of the total funding ($10.2 billion) is allocated to nonstructural risk reduction projects coast wide, and $3.8 billion of funding is allocated to 11 different sediment diversion projects.

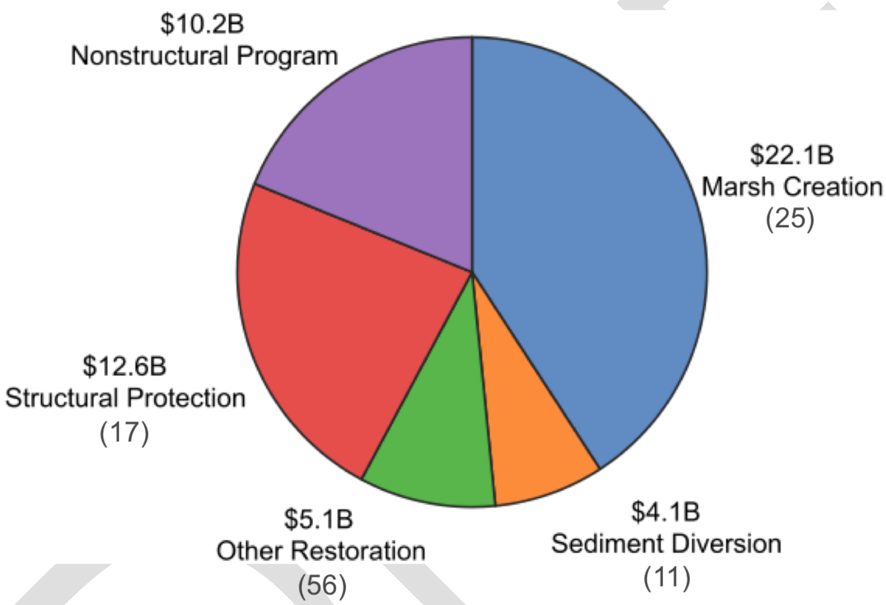

Figure 2: 2012 Coastal Master Plan Funding Allocation across Project Types.
Note: Indicated values are in 2010 U.S. dollars. The number of projects is indicated in parentheses.

Figure 3 shows that the implementation of the master plan is projected to dramatically decrease expected annual damage (EAD)[2] from coast wide flooding, from a currently estimated annual level of $2.2 billion today to between $2.8 billion and $4.8 billion in year 50 with the full implementation of the 2012 Coastal Master Plan. Without the 2012 Coastal Master Plan in place, EAD could exceed $20 billion under the less optimistic scenario. Note that the projected

[2] EAD represents the average damage estimated to occur from a storm surge flood event in any given year, taking into account both the projected chance of a storm occurring and the damage that would result.

reduction in risk from the 2012 Coastal Master Plan would be due to both restoration and risk reduction projects.

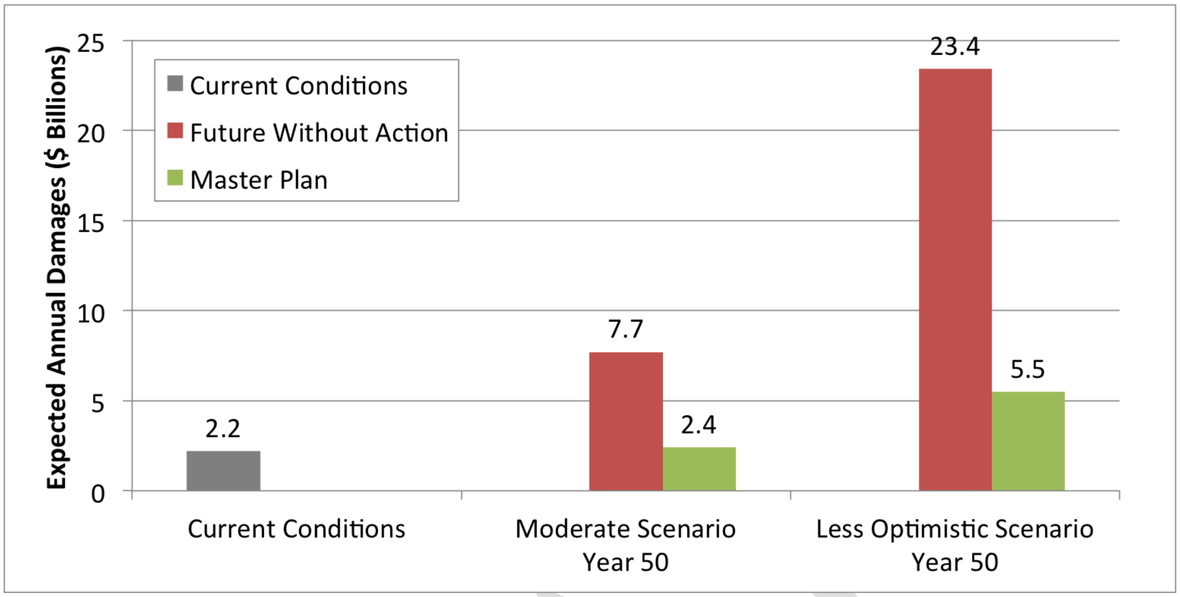

Figure 3: Reduction in Coast Wide Risk with and without the 2012 Coastal Master Plan.
Source: Coastal Protection and Restoration Authority (2012).

Figure 4 graphically illustrates this flood risk reduction under the less optimistic scenario assumptions by showing the change in future 100-year flood depths – or flood depths that would have a 1% chance of occurring in any year – with the 2012 Coastal Master Plan in place, as compared to a future without action (FWOA). The areas marked in blue face deeper levels of flooding; areas marked in orange face less flooding. Of note are the dramatically reduced flood depths projected in New Orleans, a result of several upgrades to the existing system (itself substantially upgraded since Hurricane Katrina). The extensive construction of new levees over broad areas of the central coast could also provide substantial flood depth reduction of between four and 12 feet for 1% annual exceedance probability (AEP) events, given the assumptions of the less optimistic scenario.

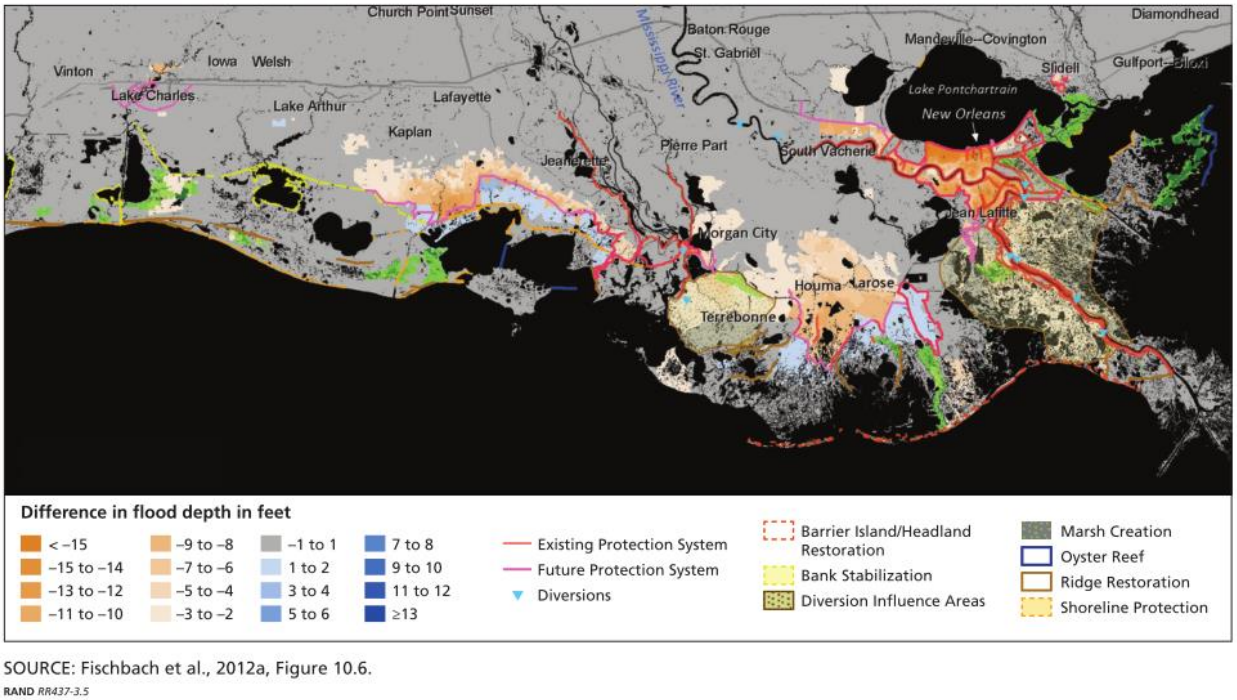

Figure 4: Reduction in 100-year Flood Depths in 50 Years Due to 2012 Coastal Master Plan (Less Optimistic Scenario).
Source: Fischbach et al. (2012, fig. 10.6).

Compared to the FWOA, the restoration projects included in the 2012 Coastal Master Plan could build between 580 and 800 square miles of land over the next 50 years, depending on future conditions, as illustrated in Figure 5. For the moderate scenario, net land loss would be halted in about 20 years, and coast wide land would then begin to increase for the remaining 30 years. For the less optimistic scenario, net land loss would still continue but at about half the rate as without the 2012 Coastal Master Plan. If future conditions are more like those represented by the less optimistic scenario, additional investments would need to be made to achieve sustainability of the landscape.

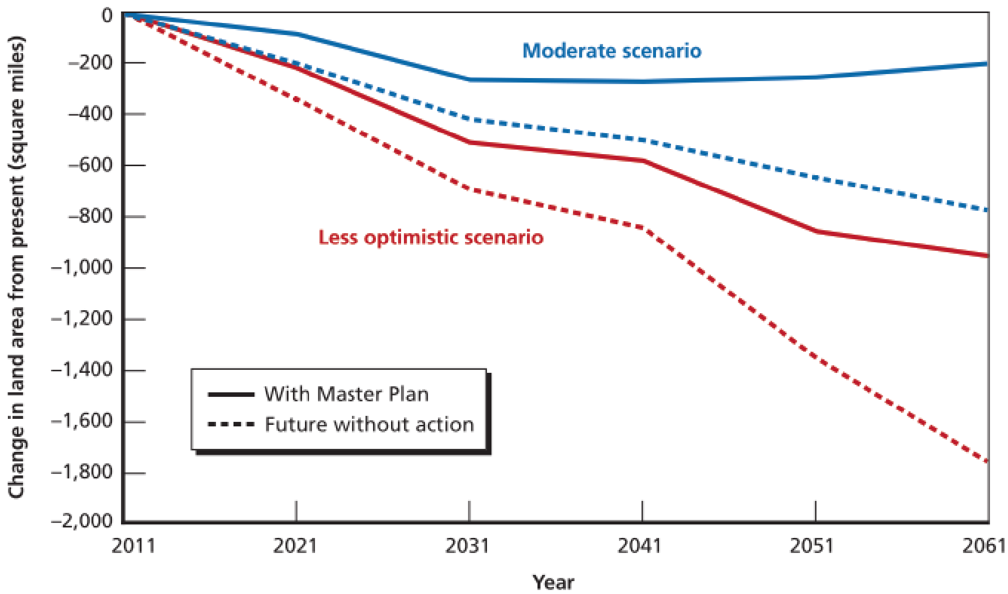

Figure 5: Change in Land Area with and without the 2012 Coastal Master Plan.
Source: Groves et al. (2013).

1.2.2 Use of Planning Tool to Support the 2017 Coastal Master Plan

Since the 2007 Coastal Master Plan, CPRA has procured nearly $15.5 billion to support planning, engineering and design, and construction of 94 restoration and protection projects. Scientific understanding of coastal processes, how the coast will evolve in the future, and the effects of coastal investments continue to be incomplete. As such, CPRA has continued to invest in data, modeling, and the Planning Tool.

For the 2017 Coastal Master Plan, CPRA updated its 50-year estimates of coastal conditions reflecting the new projects that have begun and improved data and modeling. The Planning Tool re-evaluated the projects selected for the 2012 Coastal Master Plan along with new projects proposed by stakeholders through a structured process completed in 2014. In addition, a small set of projects that was high performing but not selected in 2012 due to the budget constraint, was also re-evaluated. The Planning Tool was used to help formulate and evaluate a more refined set of nonstructural risk reduction projects. In total, CPRA evaluated the performance of 155 specific risk reduction and restoration projects and nonstructural options for 54 coastal regions with respect to more than 50 ecosystem and risk metrics.

Lastly, the Planning Tool was used in an iterative process to define risk and restoration alternatives over three environmental scenarios, six funding scenarios, and a range of different other planning consideration. The final alternatives then provided the basis for the master plan.

1.3 Purpose of this Report

This report describes the planning framework and Planning Tool, details the methodology, and defines how it is used to help formulate the 2017 Coastal Master Plan. It is designed to augment the 2017 Coastal Master Plan and its other relevant appendices[3] by providing analytic details relevant to the plan's development and serving as a reference for the underlying analysis. The intended audience of the report includes CPRA planners and management, stakeholders, and any reader of the 2017 Coastal Master Plan interested in better understanding the technical details of the Planning Tool analysis.

2.0 Planning Tool Methodology

The CPRA planning framework combines two sets of analytic capabilities: integrated models of the coastal system and a Planning Tool. Together, they are used to iteratively support the development of the 2017 Coastal Master Plan. Figure 6 illustrates the framework in flowchart form.

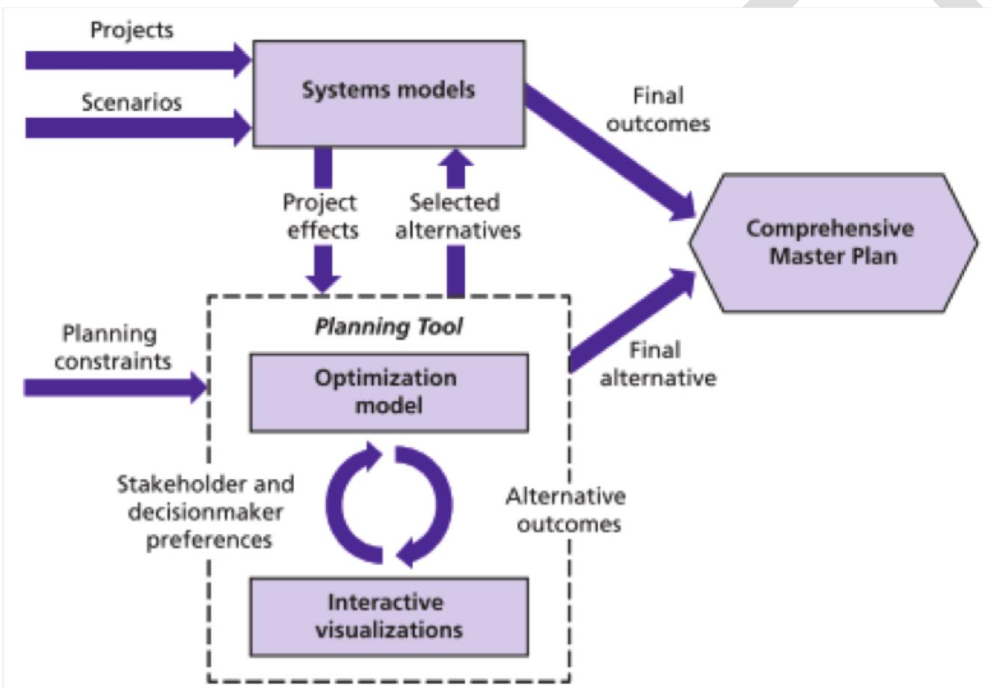

Figure 6: CPRA Analytic Framework.
Source: Groves et al. (2013).

The beginning of the process is represented at the top left of the flow chart. Analysis begins by using the systems models to evaluate how proposed coastal restoration and risk reduction projects would individually affect the coast over the next 50 years relative to no action for multiple future scenarios. Specifically, the systems models estimate the effects that each project would have on the coastal landscape, including barrier islands and wetlands; on future storm surges, waves, flooding, and flood damage; and on ecosystem characteristics, including habitats for different aquatic and land-based species. Additional calculations provide rough

3 Appendices of interest include: Appendix A (Project Definition), Appendix C (Modeling), and Appendix E (Flood Risk and Resilience Program Framework).

assessments of impacts on navigation, communities, the oil and gas industry, and other key assets.

The models' results serve as inputs to the Planning Tool, a computer-based decision support software system, along with planning constraints such as availability of sediment, potential funding over the next five decades, and the preferences of the CPRA Board and stakeholders. The Planning Tool uses optimization to identify alternatives comprised of the projects that build the most land and reduce the most flood risk while meeting funding and other planning constraints and stakeholder preferences. The Planning Tool generates interactive visualizations that summarize information about individual projects and alternatives.

In the last step, the systems models evaluate together one or a few alternatives defined by CPRA, informed by stakeholders and the Planning Tool. The specific projects for the final alternative from the Planning Tool and the outcomes estimates by the systems models provide key information to describe the master plan and its effects on the coast.

This section describes the Planning Tool's theoretical basis, scope of analysis, structure, key inputs, and specific methods for performing its key functions.

2.1 Theoretical Basis

The Planning Tool brings together several well-established planning methodologies in a customized way to meet Louisiana's planning needs. Specifically, the Planning Tool combines elements of Multi-Criterion Decision Analysis (MCDA) and Robust Decision Making (RDM) within an overarching deliberation-with-analysis process.

The National Research Council (NRC) recommends a deliberation-with-analysis approach (NRC, 2009) to support complex environmental planning challenges. This approach uses data and models not to recommend a specific course of action, but rather to help articulate potential outcomes among different reasonable courses of action over plausible futures. These results are then presented to decision makers and stakeholders to support their deliberations. The Planning Tool supports this process by using the results of the systems models and other planning data to make comparative calculations and formulate alternatives and then present interactive visualizations to CPRA and stakeholders as they make decisions about which projects to include in the 2017 Coastal Master Plan.

The Planning Tool generates alternatives that maximize the goals of the 2017 Coastal Master Plan while satisfying a wide range of constraints. MCDA (Keeney and Raiffa, 1993; Lahdelma, Salminen, & Hokkanen, 2000; Kiker et al., 2005; Linkov et al., 2006) is a standard approach to defining alternatives that conform to a set of preferences, as reflected by a corresponding set of weights. Challenges applying standard MCDA to Louisiana's coastal planning problem include:

- Evaluating interactions, synergies, and conflicts among different projects,
- Developing quantifiable coastal performance metrics that can be placed on a consistent scale for comparison,
- Interpreting the meaning of a single objective function comprised of tens of different metrics, and
- Deriving weights for each metric that represent the wide range of stakeholder views.

The Planning Tool, therefore, uses a simplified MCDA methodology. Rather than including all decision drivers within an objective function, the Planning Tool uses a simple and easily understood objective function made up of only mid-term and long-term risk reduction and land building, with a corresponding set of weights that equally balances across all four factors. It considers other coastal outcomes as constraints (Romero, 1991). The Planning Tool then uses standard mixed-integer programming (MIP) methods (Schrijver, 1998) to maximize the objective function subject to funding and other planning constraints.

To address the significant uncertainty in estimating future coastal conditions, the Planning Tool supports the comparison of projects and formulates alternatives based on estimates of future coastal conditions for different future scenarios. RDM techniques help evaluate the various alternatives and suggest a robust, adaptive alternative (Groves & Lempert, 2007; Lempert et al., 2013; Lempert, Groves, Popper, & Bankes, 2006; Lempert, Popper, & Bankes, 2003). Specifically, RDM helps identify near-term projects for implementation and specific pathways for future investment based on the evolution of future conditions. The following sections describe how these methodologies are used to support the 2017 Coastal Master Plan.

2.2 Scope of Analysis

The 2017 Coastal Master Plan framework, systems models, and Planning Tool are designed to help CPRA design a multi-billion, 50-year investment plan to address Louisiana coastal land loss and flood risk challenges. To do so, they consider how the coast would change in the coming five decades with respect to a wide range of ecological and flood outcomes. These changes are impossible to predict with certainty, so the framework, models, and tool evaluate different scenarios representing different plausible futures. The systems models then evaluate hundreds of different projects individually and then as groups of projects – or alternatives. Summaries of these results are provided to the Planning Tool. The Planning Tool presents the results of these analyses to CPRA and stakeholders through interactive computer-based visualizations to support deliberations over the many different approaches.

2.2.1 Time Horizon and Granularity

The CPRA Planning Tool evaluates projects and alternatives over a 50-year time horizon, starting from an initial condition out to 50 years into the future.

As described below, the Planning Tool receives estimates about future conditions for specific slices in time. For ecosystem-related metrics, the models produce yearly estimates, but provide estimates to the Planning Tool at 5-year intervals, which was viewed as sufficient to capture temporal variability of the ecosystem outcomes. For risk-related metrics, risk models estimate risk for initial conditions and years 10, 25, and 50 only. Data at each of these time slices are provided to the Planning Tool.

For restoration projects, the Planning Tool uses three defined periods of implementation; the first being 10 years long and the second two each being 20 years long:

- Implementation Period 1: Years 1 – 10
- Implementation Period 2: Years 11 – 30
- Implementation Period 3: Years 31 – 50

CPRA specified that the first implementation period be ten years long. This length is sufficiently long to accommodate the engineering, design, and construction time of most of the projects under consideration. It is also short enough to represent a set of near-term decisions. The remaining forty years was then divided evenly into two additional implementation periods.

The Planning Tool compares restoration projects and formulates alternatives by considering the effects of projects on the coast at two time slices:

- Near-term: year 20
- Long-term: year 50

The two periods were selected to explicitly represent CPRA's objective to consider both near-term and long-term benefits of the master plan.

Figure 7 shows graphically the three implementation periods, with each bar representing a notional project selected for a specific period, and shows the time slices used for project evaluation and alternative formulation. As described below (see Section 2.5.3.2), project effects are offset by the period of implementation. As such, projects implemented in period 3 are only evaluated in terms of their long-term effects on the coast. Section 2.5.3.3 describes how projects are sequentially selected for each of the three implementation periods.

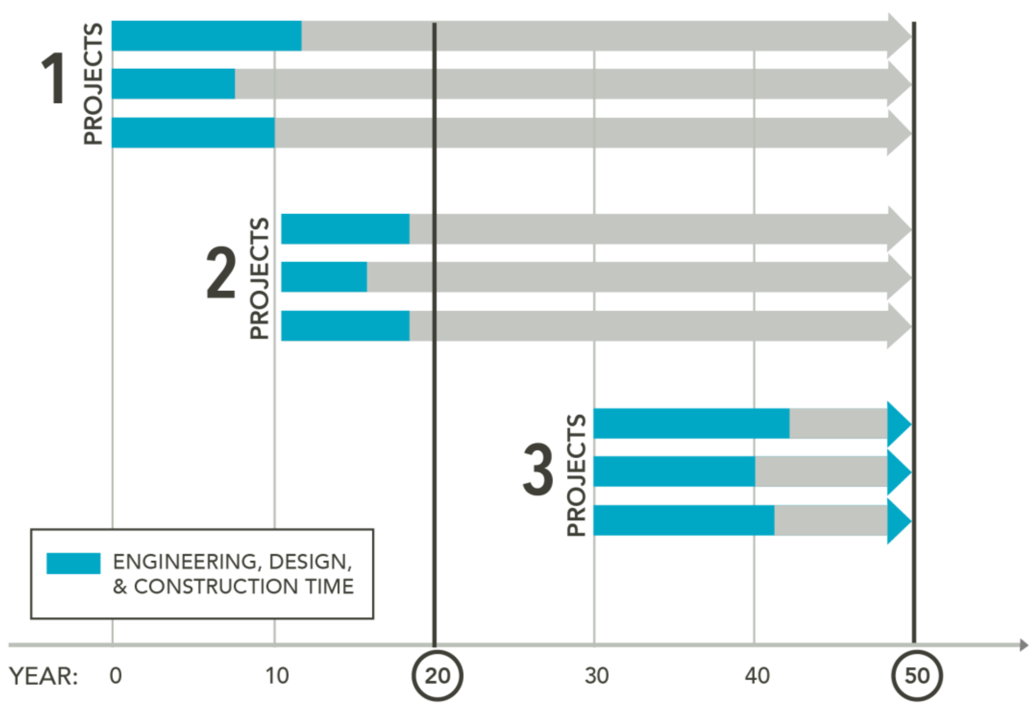

Figure 7: Implementation Periods and Evaluation Time Slices for Notional Restoration Projects.
Notes: The darkly shaded portions of the bars indicate hypothetical engineering, design, and construction times. The lightly shaded portions of the bars indicate ongoing operations and maintenance time.

For risk reduction projects, the Planning Tool selects projects differently than for the restoration projects. First, because the risk models estimate flood risk at year 25, and not year 20, a mid-term (year 25) time slice is evaluated, along with the long-term (year 50) time slice. Second, as the effects of risk reduction projects at a given point in time is not dependent on how much time has elapsed after its implementation (unlike restoration projects), the Planning Tool does not have information to favor the implementation of a project in period 1 over period 2, as it does for restoration projects. Therefore, the Planning Tool combines the first two planning periods, leading to two defined periods of implementation:

- Implementation Period 1/2: Years 1 – 30
- Implementation Period 3: Years 31 – 50

To most efficiently identify the projects that maximize long-term and mid-term benefit, the Planning Tool first selects the complete set of projects assuming a single 50-year period of implementation, based on the projects' long-term (year 50) effects (Phase 1 in Figure 8). Next, the Planning Tool determines which of these projects to implement in Implementation Period 1/2 based on mid-term (year 25) effects (Phase 2 in Figure 8).

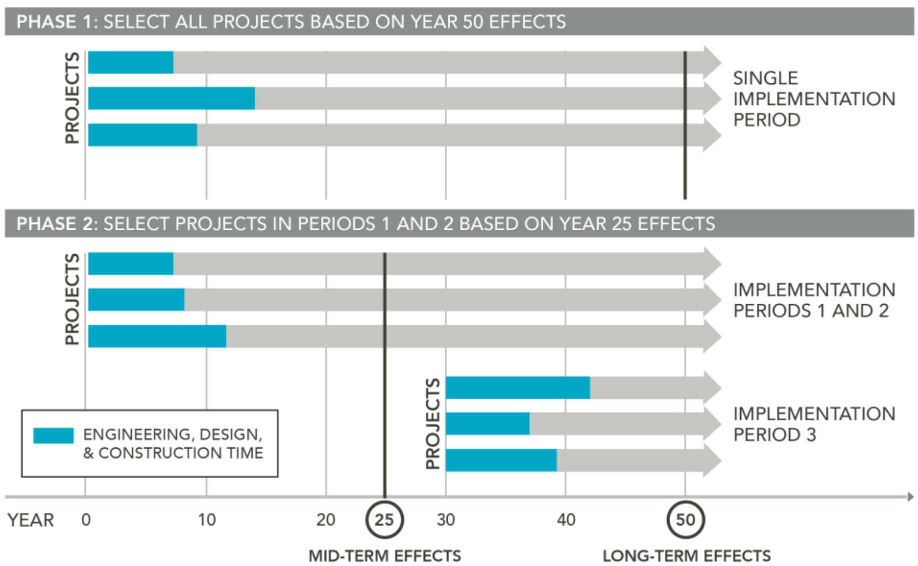

Figure 8: Implementation Periods and Evaluation Time Slices for Risk Reduction Projects.
Notes: The solid portions of the bars indicate hypothetical engineering, design, and construction times. The dashed portions of the bars indicate ongoing operations and maintenance time.

2.2.2 Systems Models

A suite of systems models provides input to the Planning Tool related to coastal ecosystem and flood risk conditions (see Meselhe et al., 2015 for details on the modeling for the 2017 Coastal Master Plan).

The Integrated Compartment Model (ICM) analyzes landscape and ecosystem performance under different environmental scenarios. It estimates hydrodynamic changes and response in land-water and vegetation. A set of 19 Habitat Suitability Indices (HSIs) are integrated into the ICM and provide estimates of a variety of aquatic and terrestrial species habitat. An Ecopath with Ecosim model (EwE) is used to derive spatially explicit estimates of fish and shellfish relative biomass.

On the flood risk side, the Advanced Circulation-Simulated Wave Nearshore model (ADCIRC-SWAN) estimates storm surge and waves for a large set of simulated tropical storms and hurricanes. The surge and wave results then serve as input to the Coastal Louisiana Risk

Assessment Model (CLARA), which translates storm surge into flood depths, as influenced by levees and other structural risk reduction projects (Fischbach et al., 2012). CLARA then calculates the resultant damages to a wide array of coastal assets. By evaluating the results of different modeled storms, statistical flood risk metrics, such as EAD, are computed.

2.2.3 Decision Drivers and Metrics

The Planning Tool evaluates projects and outcomes based on a large set of metrics that are related to the five master plan objectives listed in the introduction above. Through the 2012 Coastal Master Planning process, however, CPRA defined two factors as decision drivers – land area and flood risk reduction – represented by the land and EAD metrics, respectively. CPRA used the decision drivers to guide the alternative formulation because they are key requirements for all five of the master plan objectives, are well understood, and were shown to simplify the analysis without losing the flexibility for refining the plan. Specifically, CPRA used additional ecosystem and risk metrics as report outputs and to shape the alternatives by constraining the optimization to meet different outcome thresholds. Outcome thresholds were defined through the iterative alternative formulation approach, as described in Section 2.5.4. This same approach is being carried forward for the 2017 Coastal Master Plan.

2.2.3.1 Ecosystem Metrics

The systems models, mentioned above, calculate and supply a wide range of ecosystem metrics to the Planning Tool. These metrics include land, which is a decision driver, and other metrics from the ICM and EwE (Table 1).

Table 1: Ecosystem Metrics.

Source	**Ecosystem Metrics**
ICM	Land (square kilometers) Trajectory of land beyond the planning horizon, when a project is implemented in year 30 (difference in land between modeled year 30 and year 20) (square kilometers) Nitrogen uptake (kg) Species habitat (habitat units) • Oysters, Shrimp (brown/white), Largemouth Bass, Juvenile Menhaden, Spotted Seatrout, Bay Anchovy, Blue Crab, Brown Pelican, Mottled Duck, Green-winged Teal, Gadwall, Alligator, and Crawfish Wetland type (square kilometers) • Freshwater Wetlands, Forested Wetlands, Fresh Marsh, Intermediate Marsh, Brackish Marsh, Saline Marsh, Bare Ground, Upland, Open Water
EwE	Species biomass (tonnes/square kilometer) • Over 20, including Spotted Seatrout, Red Drum, Black Drum, Largemouth Bass, Catfish, Anchovy, Blue Crab, Brown Shrimp, White Shrimp, Gulf Menhaden, and Oyster

All the metrics are aggregated by 11 ecoregions and provided every five years from initial conditions to year 50 (Figure 9), except for the trajectory of land. The 11 ecoregions were developed by the modeling team to summarize the highly detailed modeling output. The ecoregions were defined to represent regions with similar geomorphology and ecological function.

Results for species habitat are reported as three-year averages, ending with the 5-year value. For example, the year-10 habitat value is an average of annual results for years 8, 9 and 10.

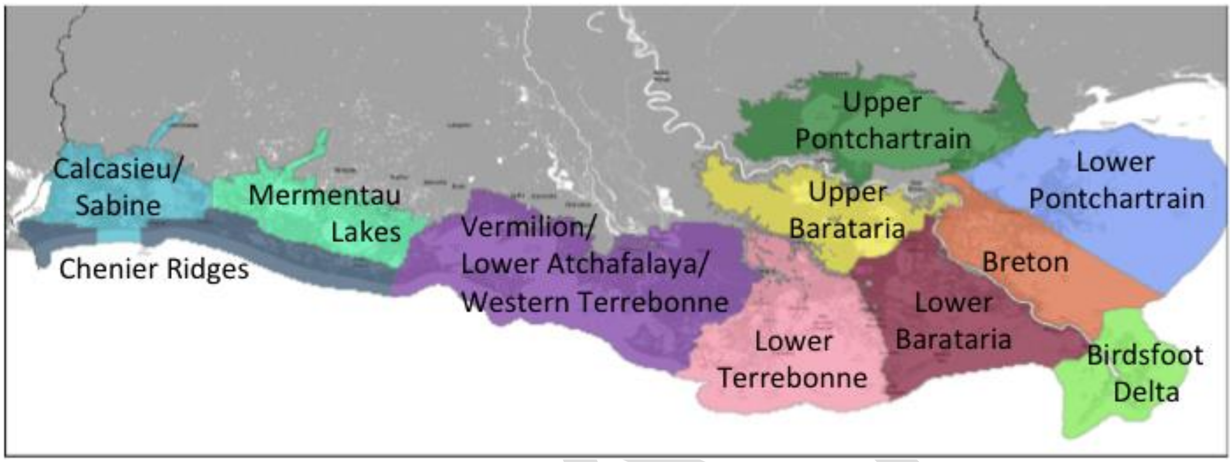

Figure 9: Ecoregions.

2.2.3.2 Risk Metrics

Risk results are provided to the Planning Tool by the CLARA model in terms of EAD, which is a decision driver. CLARA reports a mean and standard deviation value for EAD, as this is a probabilistic calculation in CLARA. To date, the Planning Tool analysis has focused on the mean EAD variable (Table 2). Results are aggregated by 54 risk regions and provided for initial conditions and years 10, 25, and 50. See Fischbach et al. (2015) for details on the risk metrics and project areas.

Table 2: Risk Metrics.

Source	Risk Metric
CLARA	Expected Annual Damage – EAD ($) • 50th Percentile, mean, and standard deviation

2.2.3.3 Additional Derived Metrics

There are a few additional metrics used to represent the effects of projects and/or alternatives that are derived from results for the ecosystem metrics, risk metrics, or both metrics. They include:

- Use of natural processes (index)
- Support for navigation (index)
- Support for traditional fishing communities (index)

- Support for oil and gas activities and communities (index)
- Support for agricultural communities (index)
- Social vulnerability (index)
- Flood protection of historic properties (%)
- Flood protection of strategic assets (%)
- Flood depths at various recurrence intervals (e.g., 50-, 100-, and 500-year) and times (i.e., initial condition, year 10, year 25, and year 50) (m)

2.2.4 Scenarios

Two sets of scenarios are being used to reflect uncertainty about future conditions – environmental and risk. All ecosystem metrics are evaluated for each environmental scenario. The risk metrics are additionally evaluated for each risk scenario.

2.2.4.1 Environmental Scenarios

For the 2017 Coastal Master Plan, three environmental scenarios have been developed. They are based on variations of the following six variables across plausible ranges established through a review of the literature (see Chapter 2 of Meselhe et al., 2015):

- Eustatic Sea Level Rise (ESLR)
  - Plausible range: 0.14 to 0.83 m over 50 years
- Subsidence
  - Plausible range: spatially variable (same as 2012 regions and values)
- Precipitation
  - Plausible range: -5% to +14% of the 50-year observational record
- Evapotranspiration
  - Plausible range: -30% to historical 50-year observational record
- Tropical Storm Frequency
  - Plausible range: For all tropical storms, -28% to no change
- Tropical Storm Intensity
  - Plausible range: +4% to +23% increase in central pressure deficit

Table 3 summarizes the differences among the three environmental scenarios. See Chapter 2 of Meselhe et al., (2015) for a discussion of how the scenarios were defined. Although tropical storms are incorporated into the ICM, tropical storm intensity and frequency only vary in the risk analyses in CLARA.

Table 3: Environmental Scenarios for the 2017 Coastal Master Plan.

Scenario	ESLR (m/50yr)*	Subsidence	Precipitation	Evapotranspiration	Overall Storm Frequency	Average Storm Intensity
	Used in ICM				Used in CLARA	
Low	0.43	20% of range	> historical	< historical	-28%	+10.0%
Medium	0.63	20% of range	> historical	historical	-14%	+12.5%

Scenario	ESLR (m/50yr)*	Subsidence	Precipitation	Evapotranspiration	Overall Storm Frequency	Average Storm Intensity
High	0.83	50% of range	historical	historical	0%	+15.0%

*rate of change is not linear

2.2.4.2 Risk Scenarios

Estimates of future risk depend upon the environmental scenario and two additional scenario factors – economic growth and structural risk reduction system fragility (Fischbach et al., 2015).

The economic growth scenarios define how much growth in the number of residential and commercial structures occurs over the 50-year planning horizon and how it is distributed throughout coastal Louisiana. Three growth scenarios reflect a range of plausible future conditions:

- Historical growth
- Concentrated growth
- No growth

The fragility scenarios reflect different assumptions about how structural risk reduction projects would perform. The three fragility scenarios are:

- No fragility
- IPET fragility – the assumptions used in the 2007 Interagency Performance Evaluation Task Force (IPET) study of the New Orleans hurricane protection system performance during Hurricane Katrina (IPET, 2007)
- Morganza to the Gulf fragility – the assumptions used in the 2013 Morganza to the Gulf study (USACE, 2013)

Note that because estimates of the future landscape vary based on the environmental scenarios, all risk calculations are evaluated across the combination of environmental scenarios and risk scenarios, for a total combination of 27 future conditions.

2.2.5 Projects

The systems models evaluated 155 structural risk reduction and restoration projects and seven nonstructural project variants for each of 54 nonstructural project areas – first individually and then as a part of alternatives. These projects are distributed across the coast, as shown in Figure 10. To learn more about the process by which CPRA evaluated the list of candidate projects for consideration in the 2017 Coastal Master Plan, see Appendix A of the master plan.

Individual risk reduction projects are evaluated relative to FWOA risk conditions (assuming the FWOA landscape) by the risk models (ADCIRC-SWAN and CLARA), and individual restoration projects are evaluated relative to FWOA landscape conditions by the ecosystem models (ICM and EwE). When evaluating alternatives, the ecosystem models can evaluate all restoration and risk reduction projects together. ADCIRC-SWAN and CLARA can then use the resulting coastal landscape including restoration project effects to evaluate storm surge flooding and risk with the alternative's structural and nonstructural risk reduction projects implemented. In this way, the modeled alternatives can capture 1) the effects that landscape changes due to restoration projects would have on risk, and/or 2) the effects that structural risk reduction projects would have on the ecosystem metrics.

2.2.5.1 Risk Reduction Projects

The 2017 Coastal Master Plan evaluated 20 structural risk reduction projects.[4] Some were selected in the 2012 Coastal Master Plan, and others are new inclusions.

While the restoration and structural risk reduction projects evaluated in the 2012 Coastal Master Plan were specific and discrete, the nonstructural projects were a representation of mitigation measures that would apply to numerous structures in a specific project area. As described in Section 2.5.1, a new set of nonstructural projects was formulated for 54 nonstructural project areas for the 2017 Coastal Master Plan. Each nonstructural project identifies the number of structures and costs for elevating, floodproofing, and acquiring properties to reduce flood risk. For each project area, several different project variants were defined to represent different ways of determining how many and which structures need nonstructural risk reduction measures.

CLARA estimates the effects on flood risk of both types of risk reduction projects – structural and nonstructural – in terms of flood depths, EAD, etc. using the same approach.

2.2.5.2 Restoration Projects

For the 2017 Coastal Master Plan, 135 restoration projects of the following types were evaluated:

- Bank Stabilization
- Hydrologic Restoration
- Ridge Restoration
- Shoreline Protection
- Oyster Barrier Reef
- Marsh Creation
- Sediment Diversion
- Barrier Island Restoration

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[4] The Planning Tool is considering two versions of the Larose to Golden Meadow project and three versions of the Morganza to the Gulf project.

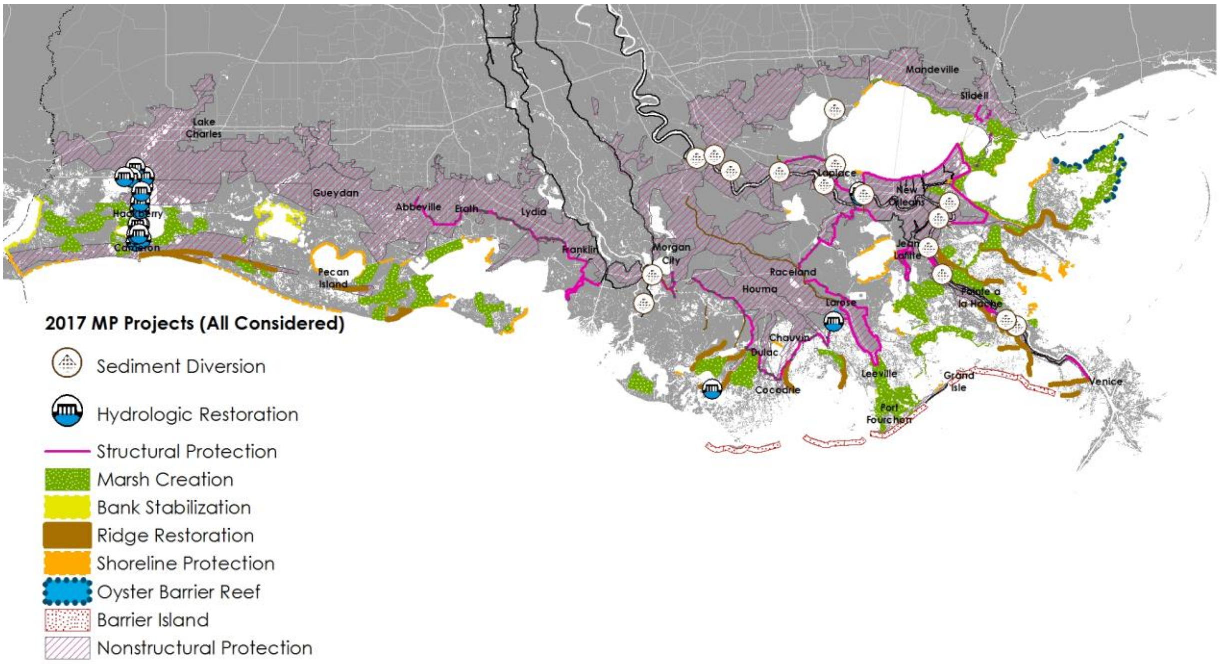

Figure 10: Restoration and Structural Risk Reduction Projects Evaluated.

2.3 Planning Tool Structure

The Planning Tool consists of three discrete elements – a database, an optimization model, and an interactive visualization package. Information is provided to the Planning Tool via structured input data sheets and user specifications of alternatives (Figure 11).

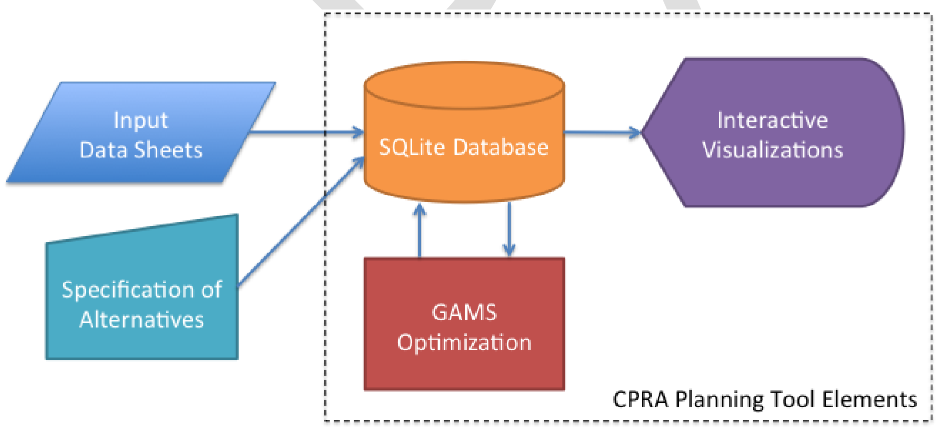

Figure 11: Planning Tool Structure.

2.4 Data

To describe the functions of and calculations performed by the Planning Tool, it is helpful to first define and describe the data that are used as inputs as well as those generated by the Planning Tool. There are several different types of data:

- **Project attributes** – information about projects
- **Outcomes** – estimates of coastal conditions without and with the implementation of projects by the systems models with respect to specific metrics
- **Constraints** – information about limitations that affect how projects can be selected as part of an alternative
- **Alternative formulation specifications** – instructions for how the Planning Tool should assemble alternatives
- **Alternative results** – Planning Tool results specifying the projects to be implemented in each period for each alternative; estimated outcomes for each alternative

For the 2017 Planning Tool, all this information is stored in a structured SQLite database.[5] The SQLite database consists of a series of tables containing data structured around a defined variable naming convention. The database structure supports the easy development of derived tables through specific database queries. The Planning Tool optimization engine and visualizations use these derived tables as input. All data stored in the database includes metadata detailing the origin of and date of the data. The SQLite database format is also portable, allowing it to be transferred to others systems for archiving or other analyses.

The subsections below describe each data source.

2.4.1 Project Attribute Data

Attribute data for each project described in Section 2 is developed to support the Planning Tool analyses. Key attribute information includes:

- Project basics
  - Name, location, type, etc.
- Project costs (present $)
  - Planning, engineering, and design
  - Construction
  - Annual operations and maintenance
- Project phase durations (years)
  - Engineering and design
  - Construction
- Project sediment requirements and sources
- Project incompatibilities

[5] More information about SQLite can be found at www.sqlite.org. The 2012 Planning Tool database was comprised of several different MySQL databases, as the approach taken by the Planning Tool underwent significant changes during the development of the 2012 Coastal Master Plan.

For two project types, Marsh Creation and Barrier Islands, the amount of sediment required to construct a project could vary depending on when the project is implemented and the future conditions (reflected by the environmental scenarios). The provisioning of sediment for these projects is also a major cost driver. Therefore, for these projects, separate estimates of sediment requirements and construction costs are provided to the Planning Tool by scenario and implementation period. For some implementation periods and environmental scenarios, the landscape conditions may not be suitable for a project to be built at all – the water levels may be too deep, for example. In these cases, sediment requirements and costs are null, and the project is indicated as infeasible for the specific implementation period.

Projects that require sediment for construction are also assigned one or more specific sources from which sediment can be acquired (see Section 2.4.5). As described below in section 2.4.5, the sediment sources are limited. This information is also stored in the Planning Tool database for use by the optimization routine.

Some projects evaluated by the Planning Tool are not designed to be implemented in conjunction with others. For example, different nonstructural project variants for the same project region have been developed, but only one of these project variants could be implemented for a given project area. The Planning Tool therefore also receives attribute information indicating which projects cannot be selected to be implemented together. This information is stored in the Planning Tool database for use by the optimization routine.

A set of scripts, developed in R (an open-source statistical programming language), is used to extract these data from a set of tables and geographic information system (GIS) layers provided by CPRA. Appendix A of this report provides additional information on the scripts and data assimilation process.

2.4.2 Future Without Action Conditions

The systems models estimate coastal conditions without projects for each environmental and risk scenario, and they summarize this information for the Planning Tool. Ecosystem outcomes are aggregated by 11 ecoregions and provided every five years to year 50 (Figure 9, above). Risk outcomes are aggregated by 54 risk regions and provided for current condition, and years 10, 25, and 50 (Table 2, above). See Section 2.2.3.2, above, for details about the regions.

These data are provided to the Planning Tool team via .csv files, with each data element identified by metric, region, time slice, and environmental or risk scenario. Another set of R scripts read these data into the Planning Tool database.

2.4.3 Future With Project Outcomes

The systems models also estimate coastal conditions for each environmental and risk scenario with each individual project implemented, assuming that engineering and design begins in year 1. For example, a marsh creation project that takes 2 years to design and engineer and 6 years to construct is modeled by adding the project into the landscape at the beginning of year 9. The results at year 10, thus, reflect the effects of the project after 2 years of completion.[6]

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[6] Note that in 2012, projects were modeled assuming construction was completed in year 0. The Planning Tool then offset benefits to account for design, engineering, and construction time, when assembling alternatives. For the 2017 analysis, this step is now unnecessary.

The future with project (FWP) outcome information is summarized and stored in the Planning Tool database in the same way as the FWOA condition (see Section 2.4.2), except with an additional identifier indicating the project.

2.4.4 Project Effects

For metrics with FWOA and FWP estimates, the Planning Tool calculates the project effects by subtracting the FWOA condition from the FWP estimate for each region, time slice, and scenario:

$$ProjectEffect_{p,t,r,m,f} = FWP_{p,t,r,m,f} - FWOA_{t,r,m,f}$$

where *p* = the project; *t* = time slice; *r* = *region*; *m* = metric; and *f* = scenario.

For example, the land project effect in a region in which there are 100 units of land in FWOA and 110 units when the project is implemented (FWP equals 110) is 10 units (110-100).

Project effects for some metrics are estimated in terms of changes from an unspecified baseline. For example, the systems models do not separately estimate a FWOA support for navigation metric. Rather, the FWOA condition is used as part of the way the metric assesses the effect of the project on support for navigation. For this type of metric, estimates of each project's effect on the metric (e.g., support for navigation) are provided directly.

2.4.5 Constraints

The Planning Tool considers two types of constraints – implementation constraints and outcome constraints. Implementation constraints are related to factors that limit how many or which projects could be implemented. The key implementation constraints are:[7]

- Funding
- Sediment

Funding constraints are defined with respect to risk reduction projects and restoration projects separately and for each of the three implementation periods. CPRA provided the Planning Tool team with a table that included an initial set of funding scenarios (Table 4). Note that in the Low Funding scenario, 80% of the period 1 funding would be allocated to restoration projects.

[7] For the 2012 Planning Tool, river use constraints were also used to limit the number and proximity of sediment diversion projects selected for a given alternative. For the 2017 Coastal Master Plan analysis, the set of possible sediment diversion projects is sufficiently restricted as not to require the application of a river use constraint.

Table 4: Initial Funding Scenarios Evaluated.

<table>
<tr><th rowspan="2"></th><th colspan="2">Low Funding</th><th colspan="2">High Funding</th><th colspan="2">High Funding #2</th></tr>
<tr><th>Restoration</th><th>Risk Reduction</th><th>Restoration</th><th>Risk Reduction</th><th>Restoration</th><th>Risk Reduction</th></tr>
<tr><td>Implementation Period 1</td><td>$6.4B</td><td rowspan="2">$9.6B</td><td>$7B</td><td rowspan="2">$21B</td><td>$7B</td><td rowspan="2">$28B</td></tr>
<tr><td>Implementation Period 2</td><td>$8B</td><td>$14B</td><td>$21B</td></tr>
<tr><td>Implementation Period 3</td><td>$8B</td><td>$8B</td><td>$14B</td><td>$14B</td><td>$7B</td><td>$7B</td></tr>
<tr><td>Total</td><td>$22.4B</td><td>$17.6B</td><td>$35B</td><td>$35B</td><td>$35B</td><td>$35B</td></tr>
</table>

After some initial analysis the High Funding scenarios were dropped and replaced with two risk reduction and restoration funding scenarios; one included $25B for risk reduction and restoration projects and the other included $30B for risk reduction and restoration projects. The funding distribution among implementation periods was also modified to provide more funds in the earlier periods. Table 5 shows the refined Low, Medium, and High funding scenarios.

Table 5: Refined Funding Scenarios Evaluated.

<table>
<tr><th rowspan="2"></th><th colspan="2">Low Funding</th><th colspan="2">Medium Funding</th><th colspan="2">High Funding</th></tr>
<tr><th>Restoration</th><th>Risk Reduction</th><th>Restoration</th><th>Risk Reduction</th><th>Restoration</th><th>Risk Reduction</th></tr>
<tr><td>Implementation Period 1</td><td>$6.4B</td><td rowspan="2">$11.6B</td><td>$5B</td><td rowspan="2">$20B</td><td>$6B</td><td rowspan="2">$24B</td></tr>
<tr><td>Implementation Period 2</td><td>$10B</td><td>$15B</td><td>$18B</td></tr>
<tr><td>Implementation Period 3</td><td>$6B</td><td>$6B</td><td>$5B</td><td>$5B</td><td>$6B</td><td>$6B</td></tr>
<tr><td>Total</td><td>$22.4B</td><td>$17.6B</td><td>$25B</td><td>$25B</td><td>$30B</td><td>$30B</td></tr>
</table>

Sediment constraints are defined by a set of 78 individual sediment sources (i.e., borrow areas). For sources that are not within the Mississippi River channel, a single amount of sediment is specified. For Mississippi River-based sources, sediment is considered renewable. These sources are assigned a 5-year renewable volume. Both types of sediment constraints are stored in the Planning Tool database in a simple table containing the amount of sediment available for each implementation period.

The Planning Tool uses outcome constraints during alternative formulation to consider the effects of a project with respect to outcomes other than land and EAD. These constraints use the project effects results (Section 2.4.4) together with user-specified outcome constraints (Section 2.4.6). Section 2.5.3 describes how both types of constraints are used in the alternative formulation process.

2.4.6 Alternative Specifications

For the alternative formulation function, CPRA and the Planning Tool team developed specifications for each alternative to be formulated. The specifications are recorded in an Excel-based table and include the following information:

- Meta data about the alternative

  - Intent narrative
  - Date of formulation
  - Date/version of data

- Description of objective function
- Budget scenario
- Environmental scenario (for formulation)
- Risk scenario (for formulation)
- Outcome constraints
- CPRA-specified project inclusions or exclusions

In the Planning Tool database, each alternative is assigned a unique ID number so that alternative results can be cross-referenced to the specifications used to formulate them.

For example, a set of baseline alternatives that maximize mid-term and long-term risk reduction and land for each of the three environmental scenarios would be specified as shown in Table 5.

Table 6: Example Specification for Three Alternatives.

Alternative ID	**1**	**2**	**3**
Objective Function	Max land/EAD; 50/50 MT/LT	Max land/EAD; 50/50 MT/LT	Max land/EAD; 50/50 MT/LT
Budget Scenario	$17.6 billion (Risk Reduction); $22.4 billion (Restoration)	$17.6 billion (Risk Reduction); $22.4 billion (Restoration)	$17.6 billion (Risk Reduction); $22.4 billion (Restoration)
Environmental Scenario	ES-01	ES-02	ES-03
Risk Scenario	RS-01	RS-01	RS-01

2.4.7 Alternative Results – Projects and Estimated Outcomes

When the Planning Tool formulates an alternative, it defines which projects are implemented in each of the implementation periods. Each project that is specified to be implemented begins accruing engineering and design costs in the first year of the implementation period. Construction costs are incurred immediately following engineering and design. Lastly, operations and maintenance continue through the end of the 50-year planning horizon (year 50). These results are stored in the Planning Tool database.

The Planning Tool also calculates for each alternative the expected outcomes for land, EAD, and select metrics at a 5-year interval for ecosystem metrics and at initial condition and years 10, 25, and 50 for risk metrics. See Section 2.5.3.4 for information on the specific calculation.

Other outputs from the alternative formulation calculations include:

- The cost for all restoration and risk reduction projects by implementation period (constrained by the funding scenarios)

- The required sediment by source and implementation period (constrained by the sediment source volumes)[8]

These outputs will help CPRA and stakeholders understand why the selected projects are selected. These results are stored in the Planning Tool database.

2.5 Functions

The Planning Tool performs a variety of functions in support of the CPRA master plan development, as listed and summarized in Figure 12. The subsequent subsections provide more detail for each function.

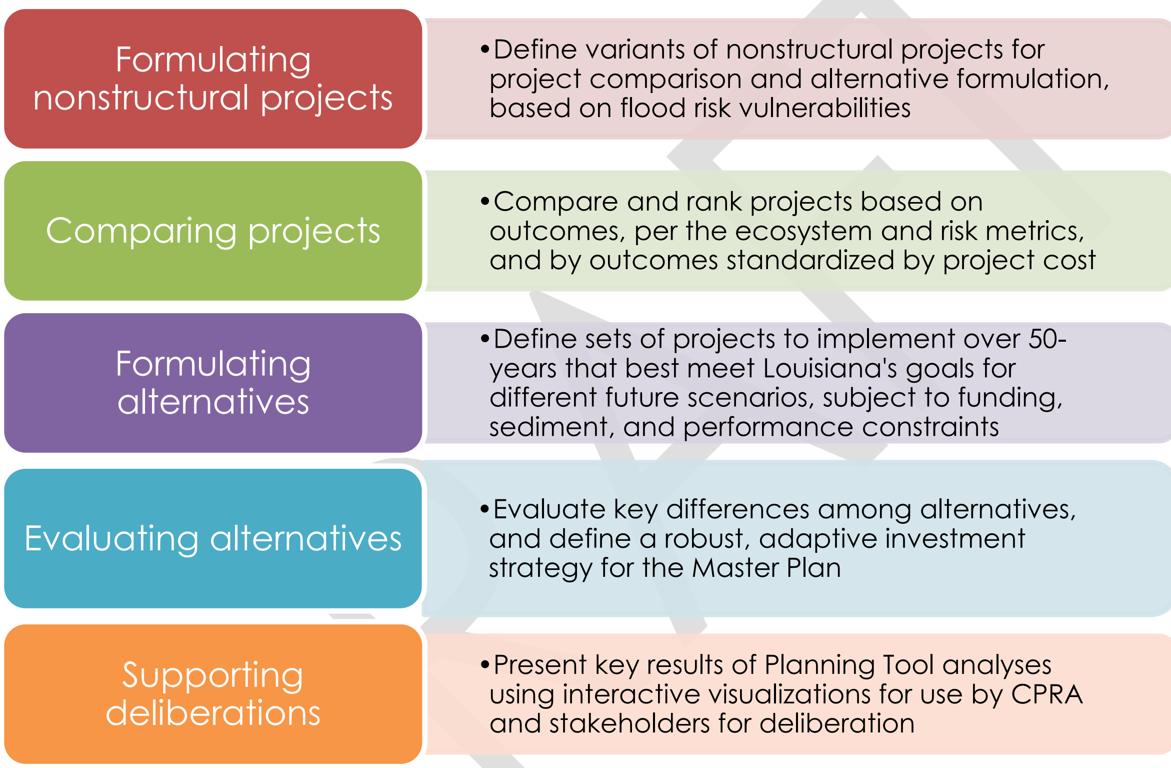

Figure 12: Planning Tool Key Functions.

2.5.1 Formulating Nonstructural Projects

For the 2017 Coastal Master Plan, CPRA developed a set of nonstructural projects (or variants) across the coast. The project variants specify nonstructural mitigation designed for different elevation standards and considerations of community characteristics, such as low-to-moderate income (LMI) households in the project areas. A wide range of nonstructural projects enables the Planning Tool to identify the level of nonstructural investment that, when combined with the structural risk reduction projects, most cost-effectively reduces risk. In some areas, only a low

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[8] This information can help determine if limited sediment availability is influencing the selection of projects for a specific alternative.

level of nonstructural mitigation will be appropriate. In other cases, more extensive nonstructural mitigation will be required to reduce risk in vulnerable communities.

Nonstructural project variants were developed for a new set of 54 nonstructural project areas defined for the 2017 Coastal Master Plan (see Fischbach et al., 2015). These nonstructural project areas were defined to consider interactions among structural and nonstructural projects at an appropriate spatial scale. Each nonstructural project area shown in Figure 13 is contained within one of the 54 risk regions.

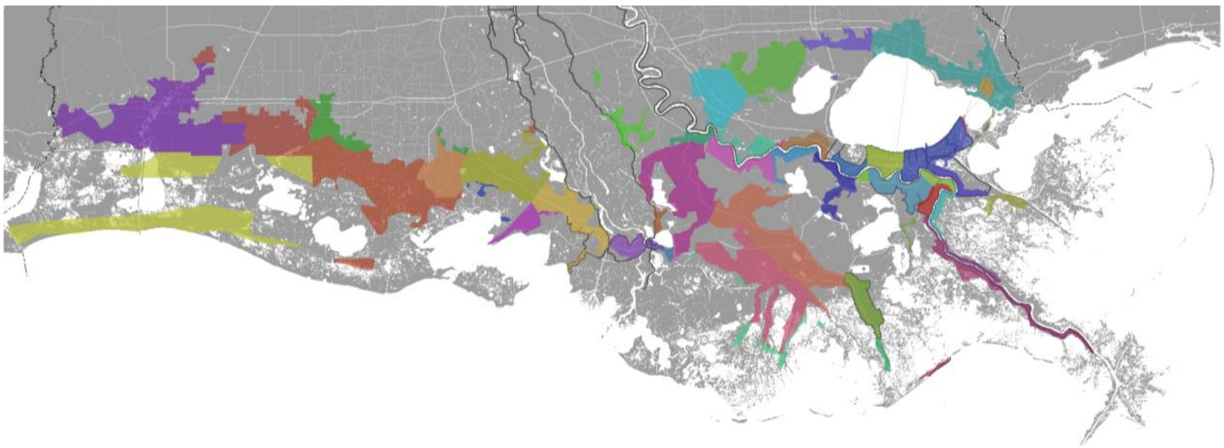

Figure 13: Nonstructural Project Areas for 2017 Coastal Master Plan.

Risk Mitigation Elevation Standards

To identify the nonstructural project variants, different risk mitigation elevation standards were considered. Each elevation standard was based on CLARA estimates of the 100-year flood depth, plus 2 feet of freeboard, at three specified future time periods – current condition, year 10, and year 25 – and for each of the three environmental scenarios described above. CLARA considered elevation standards based on the conditions shows in Table 7. These variants focus primarily on different elevation standards, although variant 5 also includes grid points with more than 30% LMI households.

Table 6: CPRA Defined Nonstructural Project Variants.

Variant	Elevation Standard		Additional Constraint
	Time slice	Environmental Scenario	
1) Current Conditions	Current conditions	n/a	n/a
2) Year 10, Low	Year 10	Low	n/a
3) Year 10, Medium	Year 10	Medium	n/a
4) Year 10, High	Year 10	High	n/a
5) Year 10, Medium, LMI	Year 10	Medium	LMI > 30%

Variant	Elevation Standard		Additional Constraint
	Time slice	Environmental Scenario	
6) Year 25, Medium	Year 25	Medium	n/a
7) Year 25, High	Year 25	High	n/a

CLARA used the calculated elevation standard at each grid-point (see below) to specify the type of mitigation for each structure:

- Commercial structures are to be floodproofed where the elevation standard is less than 3 feet
- Residential structures are to be elevated where the elevation standard is between 3 and 14 feet
- Residential structures are to be acquired if elevation standards is greater than 14 feet

Grid-Point Analysis for Different Elevation Standards

CLARA defined nonstructural mitigation for a set of grid points within the study domain. There are 90,373 total grid points in the CLARA study area for coastal Louisiana, although not all grid points have structures that are at risk to flooding. The grid has a minimum resolution of 1 km^2, with higher than 1 km^2 resolution in areas with a high density of census blocks, population, and assets (Fischbach et al., 2015). Each grid point is associated with one of the 54 nonstructural project areas, as seen in Figure 14.

Figure 14: Grid Points Used to Define Nonstructural Projects.

The CLARA team calculated for each grid point, a set of mitigation actions based on the seven different elevation standards, assuming an 80% participation rate. For each grid point and elevation standard, CLARA calculated:

- Number of structures mitigated (flood-proofed, elevated, acquired)
- Cost of mitigation

- Reduction in EAD from the nonstructural mitigation for years 10, 25, and 50, for each environmental scenario[9]

This information, along with estimates of the 100-year current and future flood depths, the percent of LMI households, and the number of repetitive and severe repetitive loss properties, was then passed to the CPRA Planning Tool for evaluation.

Defining Nonstructural Project Variants

The Planning Team next defined a set of rules that would apply to all 54 nonstructural project areas and define variants for each project area. Each variant consists of a unique set of nonstructural projects across the coast. The Planning Tool assisted in this process by interactively showing how specific rules would lead to different sets of nonstructural projects, as described below.

Each variant was defined based on the following user-specified information in the Planning Tool:[10]

- Elevation standard (i.e., year and environmental scenario for 100-year flood estimate)
- Constraint on the inclusion of grid points based on the percentage of LMI households
- Constraint on the cost-effectiveness of mitigation for each grid point, where cost-effectiveness is defined by the current-year EAD reduction divided by the cost of the nonstructural mitigation

For each set of rules, the Planning Tool depicts the number of structures floodproofed, elevated, and acquired for each grid point. Figure 15 shows these results for a variant with an elevation standard based on current 100-year flood depths.

[9] To manage the number of total scenarios evaluated at this step, we assumed historical growth and the no fragility scenarios. Differences in FWOA risk under alternative growth and fragility scenarios are small across the coast. Note that as described below, all risk reduction projects (including nonstructural projects) will be evaluated across all growth and fragility scenarios.
[10] CPRA chose not to define variants based on repetitive and severe repetitive loss properties but rather to use this information for context when defining the variants.

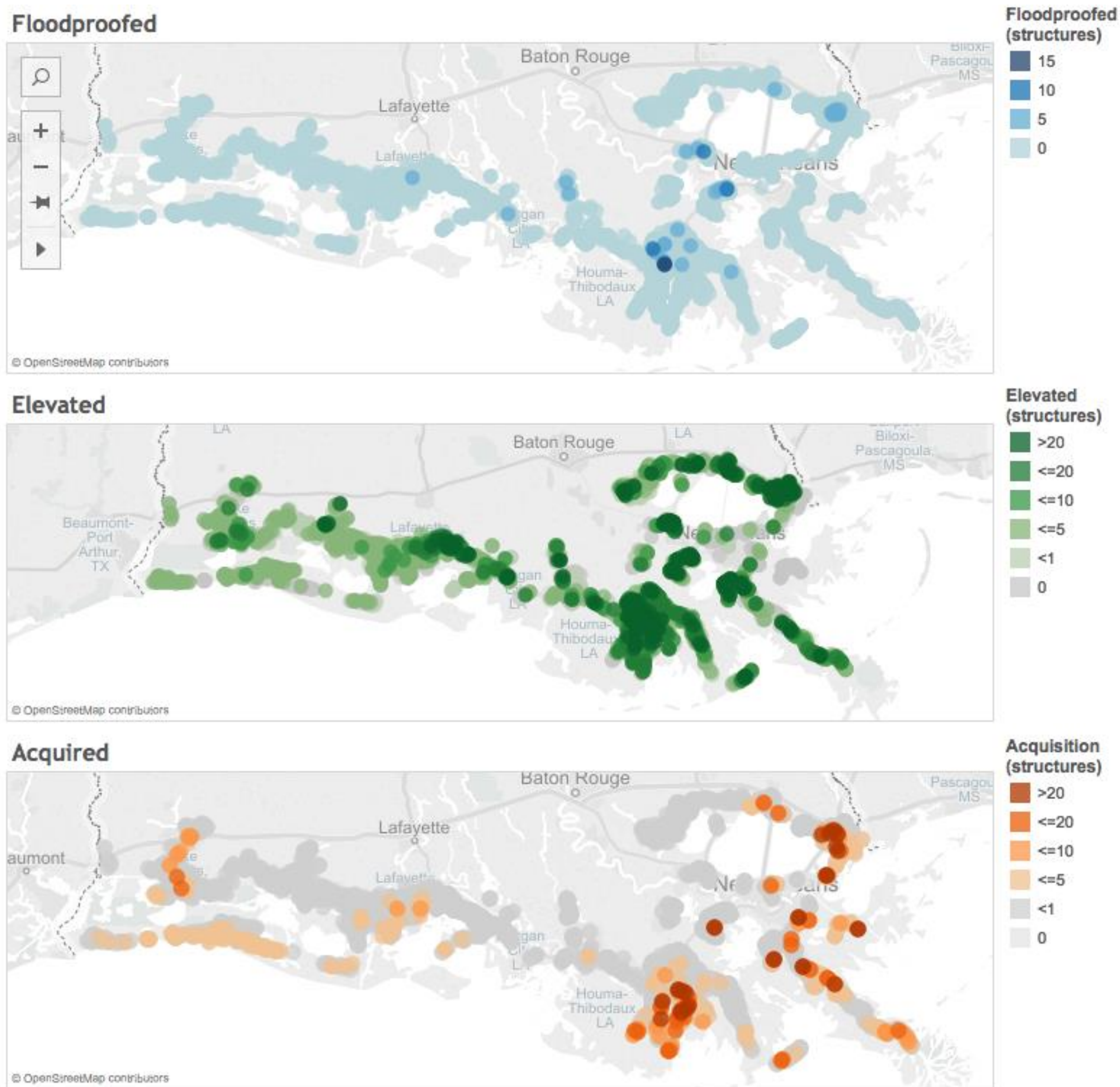

Figure 15: Number of Structures Mitigated by Grid Point for Nonstructural Project Variants Based on Current 100-year Flood Depths.

For each variant, the Planning Tool can also show for the included grid point's additional vulnerability information such as the LMI households, repetitive loss and severe repetitive loss properties, current 100-year flood depths, and year 50 100-year flood depths (Figure 16).

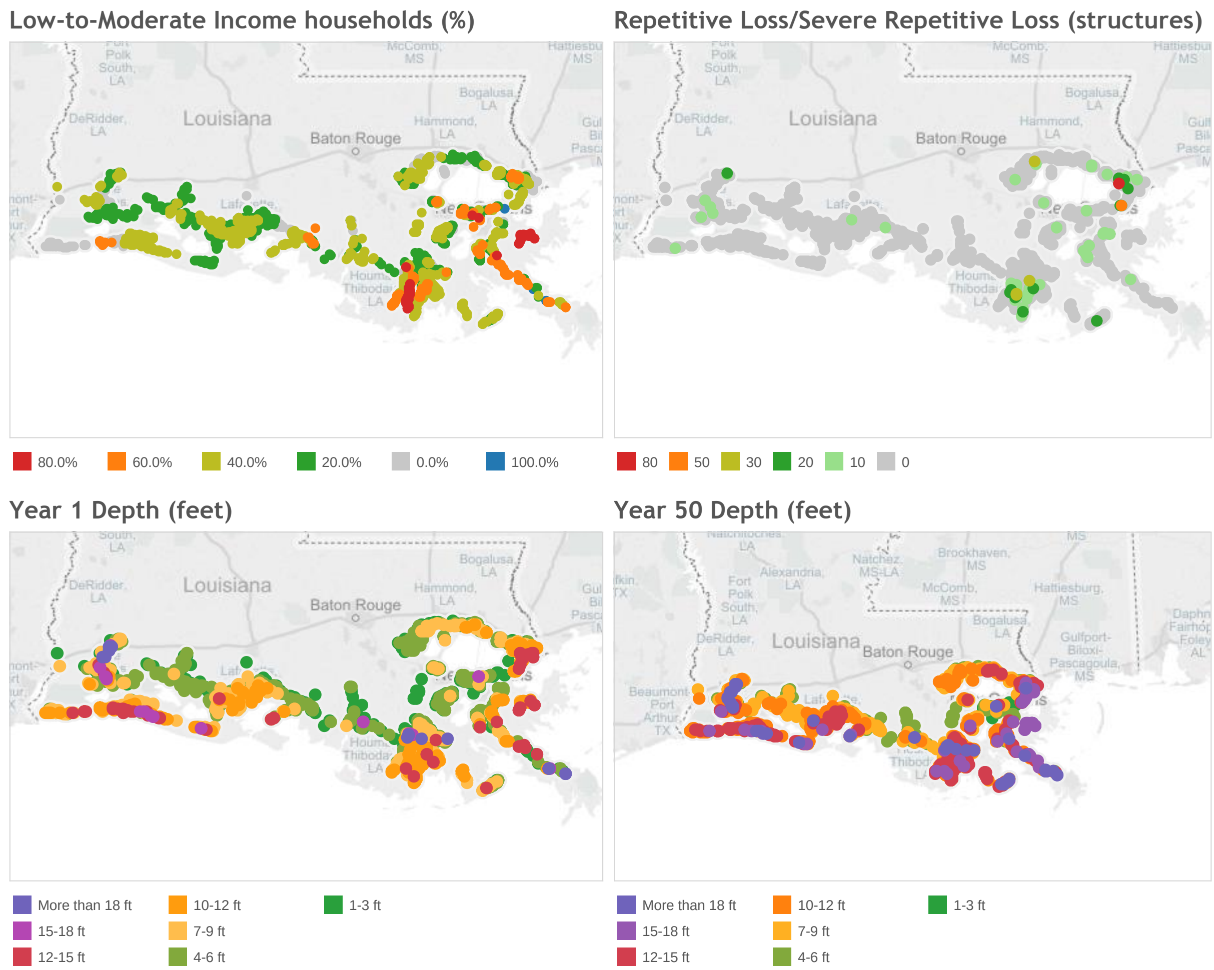

Figure 16: Vulnerability Attributes for Each Grid Point for Variant with Elevation Standard Based on Current 100-year Flood Depths.

Nonstructural Project Variants for 2017 Coastal Master Plan

To assist in the development of a range of nonstructural project variants, the Planning Tool summarized the nature of the mitigation, costs, and damage reductions for seven different specifications defined above in Table 7.

Evaluating Nonstructural Project Variants

The CLARA model next evaluated each nonstructural project for current conditions and years 10, 25, 50, and across the environmental scenarios and risk scenarios. These nonstructural project variants were compared to each other and the structural risk reduction projects (see Section 2.5.2). They are also included in the Planning Tool's process of developing risk reduction alternatives (see Section 2.5.3).

2.5.2 Comparing Projects

The Planning Tool compares individual projects based on systems model estimates of their effects on the coast and the effects scaled by total project cost. Rankings of projects by outcomes and cost-effectiveness for key metrics provide CPRA and stakeholders with a first-order assessment of which projects could most efficiently help achieve Louisiana's goals.

A project's effect on the coast is the difference between the FWP outcome and FWOA outcome for a given metric, time slice, and region:

$$ProjectEffect_{metric,timeslice,region,p} = FWP_{metric,timeslice,region,p} - FWOA_{metric,timeslice,region}$$

The Planning Tool calculates cost-effectiveness for the near-term (year 20) for restoration projects, the mid-term (year 25) for risk reduction project, and the long-term (year 50) for all projects. These calculations assume that restoration projects are implemented at the beginning of the first period, and that the project effects take into account the time required to design, engineer, and construct each project. To calculate cost-effectiveness, the effects are scaled using 50-year project costs, which include planning, design, and construction costs, plus operations and maintenance costs through the 50-year time horizon. The Planning Tool can also consider how different project costs, reflecting uncertainty in the cost estimates, would affect the project rankings.

Near-term and long-term cost-effectiveness for each restoration project, p_e, is calculated as:

$$NeartermCostEffectiveness_{ecometric,p_e} = {CoastwideProjectEffect_{ecometric,year20,p_e}}\Big/{ProjectCost_{p_e}}$$

$$LongtermCostEffectiveness_{ecometric,p_e} = {CoastwideProjectEffect_{ecometric,year50,p_e}}\Big/{ProjectCost_{p_e}}$$

where the *CoastwideProjectEffect* is equal to *ProjectEffect* summed over all ecoregions. *ProjectCost* is the 50-year cost of the project and is calculated as the sum of the costs for engineering and design (*EDcost*), construction (*Constructioncost*), and operations and maintenance ($OMannualcost$) for the remaining number of years in the 50-year planning period after the project is constructed:

$$ProjectCost_{p_e} = EDcost_{p_e} + Constructioncost_{p_e} + OMannualcost_{p_e} \times \left[50 - \left(EDtime_{p_e} + Constructiontime_{p_e}\right)\right]$$

For risk reduction projects, p_r, the Planning Tool calculates mid-term and long-term EAD cost-effectiveness scores in a similar way as for restoration projects:

$$MidtermCostEffectiveness_{riskmetric,p_r} = {CoastwideProjectEffect_{riskmetric,year25,p_r}}\Big/{ProjectCost_{p_r}}$$

$$LongtermCostEffectiveness_{riskmetric,p_r} = {CoastwideProjectEffect_{riskmetric,year50,p_r}}\Big/{ProjectCost_{p_r}}$$

In general, all restoration projects are compared based on the same set of ecosystem metrics and all risk reduction projects are evaluated based on the same set of risk metrics. There are some minor exceptions. For example, to better show how nonstructural projects that are of lower cost-effectiveness than other structural projects may be selected in regions where there are no structural options, the Planning Tool delineates the project comparisons by those areas with and those without structural risk reduction projects. This comparison can highlight the most cost-effective nonstructural projects in areas without structural risk reduction options.

The Planning Tool stores these results in the database and uses them for interactive visualizations (see Section 2.5.5).

2.5.3 Formulating Alternatives

The Planning Tool develops alternatives – defined as sets of projects to implement in each of the three implementation periods – that best achieve CPRA goals, subject to implementation and performance constraints. There is no "correct" alternative, and the Planning Tool is designed to formulate many alternatives and summarize the key differences among them. Some alternatives vary key implementation constraints such as project funding. Others have considered the effects on land or EAD outcomes if requirements for performance with respect to other metrics, such as shrimp habitat, are added. The Planning Tool is flexible and can be modified to respond to CPRA and stakeholders interests.

2.5.3.1 Overview

In general, the Planning Tool uses an optimization model to select the restoration and risk reduction projects that will maximize near/mid-term and long-term land building and EAD reduction. For the 2012 Coastal Master Plan, the Planning Tool defined the optimal projects for all three implementation periods simultaneously. While this process ensured that projects were selected so that near-term and long-term benefits were as high as possible, the procedure in some cases specified that highly cost-effective projects be delayed to later implementation periods.

For the 2017 Coastal Master Plan, the Planning Tool instead selects the optimal restoration projects for each of the three implementation periods in turn. This procedure ensures that the best projects are selected in the first implementation period, the next best in the second, and so on. CPRA believes that this approach makes the most sense given the significant uncertainty about how precisely the Coastal Master Plan will be implemented over the coming decades. Of paramount concern to CPRA is defining and implementing projects now that will most efficiently put Louisiana on a trajectory of sustainability in terms of the landscape and level of flood risk.

For restoration projects, the procedure first selects projects to implement in period 1 (years 1-10). The Planning Tool assumes that these projects are implemented beginning in year 1 and that cost and sediment requirements for the first 10 years of each project must be met by period 1 funding and sediment sources. Cost and sediment requirements can also span more than one implementation period, and any additional sediment and cost requirements must also be met by the funding and sediment sources in that later implementation period. Therefore, the available sediment and funding budget for the following implementation period is adjusted before the Planning Tool identifies projects for implementation in period 2 (years 11-30). Constraints pertaining to project compatibilities are also imposed.

The Planning Tool next selects projects to implement in period 2 (years 11-30). Any project not selected in the first implementation period is a candidate for selection. These projects are assumed to begin engineering and design in year 11 and accrue costs from that year forward. The Planning Tool ensures that all funding and sediment requirements are met. After selecting projects from implementation period 2, the same steps are performed to identify projects to implement for period 3 (years 31-50). Figure 7 shows this three-step process graphically.

In addition to maximizing near-term and long-term land, other performance constraints are considered in this process. First, since a project implemented in period 3 will only reach a life span of 20 years at the end of our evaluation period (50 years), a constraint on sustainability of land is added to ensure that these restoration projects are projects whose positive effects will persist or grow beyond year 50. The sustainability of land constraint limits restoration project selection in period 3 to those projects that have stable or increasing land effects between modeled years 40 and 50.

For risk reduction projects, the Planning Tool selects projects a bit differently. This is because their benefits do not depend on the timing of implementation—if a project is implemented is provides the estimated benefit for that project as calculated by the systems model. As such, there is no difference between projects implemented in the first implementation period (years 1-10) and those implemented in the second implementation period (years 11-30), provided that they are constructed before the mid-term time horizon—year 25. Therefore, the Planning Tool first identifies projects to include that maximize long-term (year 50) risk reduction, assuming a single 50-year implementation period. Next, the Planning Tool selects the set of projects, using funding for the first two implementation periods (or 30 years), that maximizes mid-term (year 25) risk reduction. The Planning Tool then specifies that the projects not selected in the first phase are then to be implemented in the third implementation period. Figure 8 shows this two-phase process graphically

For both risk reduction and restoration alternatives, other performance constraints can also be imposed when formulating alternatives. These constraints can help 1) to better understand whether improvements in other metrics could be achieved at a minimal effect to the decision drivers, land and EAD reduction, and 2) to ensure that specific outcomes are achieved while maximizing land area and EAD reduction. Iterative alternative formulation and review of these results support CPRA deliberations.

2.5.3.2 Data Processing

Project attribute information from CPRA and project effects information from the systems models are key inputs to the Planning Tool for alternative formulation. Before using these data to formulate alternatives, two sets of calculations are required. First, each project's cost and sediment requirements must be distributed over time in order to determine how much applies to each implementation period. The Planning Tool distributes engineering and design costs evenly across the duration of the engineering and design period, and does the same for construction costs. It then applies the annual operations and maintenance cost to each year after construction is complete. Table 7 provides an example for a project's costs and duration for each phase, and Figure 17 shows how these costs are distributed annually depending on the period of implementation.

Table 7: Example Project Phase Costs and Duration.

	Costs	**Duration**
Engineering and Design	$10M	5 years
Construction	$140M	7 years
Operations and Maintenance	$1M/year	Until year 50

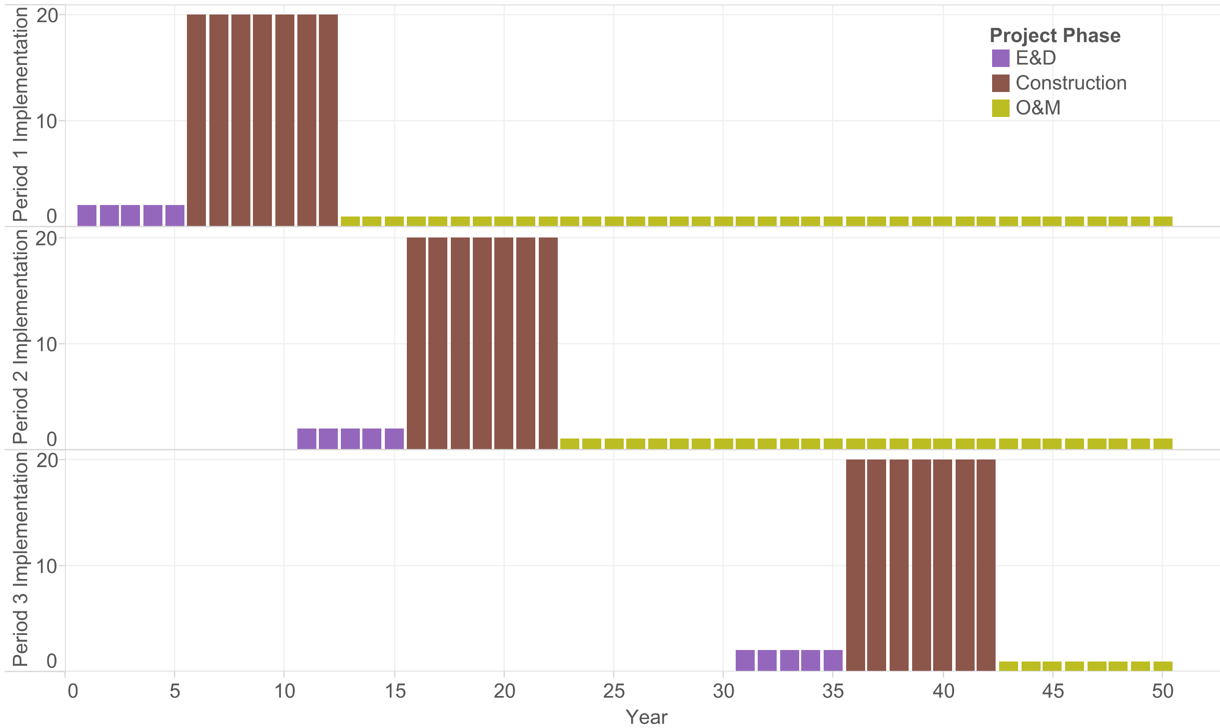

Figure 17: Example Distribution of Project Costs for Three Periods of Implementation.

For a project's sediment requirement, the total requirement is simply distributed evenly across the years in which the project would be constructed, depending on the implementation period.

The next step is to calculate the Offset Project Effects matrix, which specifies a project's effect for each metric when implemented in each of the three implementation periods. Calculating this matrix requires shifting of estimated restoration project effects by the implementation period. Note that the Planning Tool assumes that if a project is implemented in the second or third implementation periods, then the effects in the near-term (year 20) and long-term (year 50) are equal to the modeled effects, shifted by 10 years and 30 years earlier, respectively (Table 8). Effects for intermediate time periods are estimated similarly.

Table 8: Modeled Results Used to Approximate Effects of Restoration Projects Implemented in Each of the Three Implementation Periods.

	Select time slices for offset effects						
Implementation Period	Initial condition*	Year 5	Year 10	Year 20 (near-term)	Year 30	Year 40	Year 50 (long-term)
1 (years 1-10)**	Initial condition	5	10	20	30	40	50
2 (years 11-30)	n/a	n/a	0	10	20	30	40
3 (years 31-50)	n/a	n/a	n/a	n/a	0	10	20

* For some metrics, results are provided at the end of year 1, not initial condition.
** Note that there is no offset of results for implementation period 1.

For risk reduction projects, the systems models report effects at initial condition and years 10, 25, and 50, and no offsetting procedure is required.

2.5.3.3 Optimization Calculation

The Planning Tool selects projects for each implementation period using an optimization model developed in GAMS.[11] Specifically, GAMS solves a mixed integer program in which the decision variables are binary choices, *I,* to implement or not implement a project in one of the three implementation periods, *i*. The objective is a simple function including mid-term and long-term land and risk reduction. The algorithm maximizes the objective function subject to available funding and sediment, and some additional constraints defined below:[12]

$$Max \sum_{p_r} \left[-\left(offset\_effect^{*}_{EADreduction,i,year25,p_r} + offset\_effect^{*}_{EADreduction,i,year50,p_r} \right) \times I_{i,p_r} \right]$$

$$+ \sum_{p_e} \left[-\left(offset\_effect^{*}_{land,i,year20,p_r} + offset\_effect^{*}_{land,i,year50,p_e} \right) \times I_{i,p_e} \right]$$

by choosing $I_{i,pr}$ = {1 or 0}, subject to the following funding constraints:

$$\left(\sum_{p_r} I_{i,p_r} \times Cost_{i,p_r} \right) \leq RiskFunding_i$$

$$\left(\sum_{p_e} I_{i,p_e} \times Cost_{i,p_e} \right) \leq RestorationFunding_i$$

and sediment constraints (for restoration projects), for each sediment source, *s*:

$$\left(\sum_{p_e} I_{i,p_e} \times SedimentRequirement_{i,p_e,s} \right) \leq SedimentSource_{i,s}$$

and sustainability of land constraint for implementation period, *i*=3, for each restoration project, p_e:

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[11] GAMS (General Algebraic Modeling System) is a high-level modeling system. It consists of a language compiler and a stable of integrated high-performance solvers. CPLEX is used in this application.
[12] Note, that for some variables, like EAD reduction, there is a theoretical-maximum that could be achieved in each risk region – zero risk. Therefore, the function above limits the total EAD reduction for a region to the FWOA level of risk, as indicated by the "*".

$$\left(\sum_{p_e} I_{i,p_e} \times offset\_effect_{m=sustainability\_of\_land,i=3,p_e}\right) \geq g$$

where g is some specified threshold for the sustainability of land metric.[13]

The Planning Tool includes additional constraints to ensure that only one of a set of mutually exclusive projects is implemented.

Note that for non-Mississippi River sediment sources, the total amount of available sediment is made available in implementation period 1. Sediment not used in period 1 is available in implementation period 2 and so on. For river sediment sources, the Planning Tool takes the 5-year renewable amount and sets the total available sediment to be 2 times the 5-year amount for implementation period 1 and 4 times the 5-year amount for implementation periods 2 and 3. There is no carryover of unused sediment between the implementation periods.

The Planning Tool is flexible and can be adjusted to ensure that a desired mixture of projects is selected for the 2017 Coastal Master Plan. For example, if a particular type of project is not as cost-effective in terms of land (for restoration projects) or EAD (for risk reduction projects) as others; the Planning Tool could define alternatives without sufficient project diversity. While this did not occur in the 2012 Coastal Master Plan process, if it does, additional constraints could be added that require a minimum amount of expenditure on each project type. For example, this approach could be used to ensure that sufficient nonstructural projects are selected even if they are formulated to emphasize the targeting of particular vulnerabilities, such as LMI properties, at the expense of cost-effectiveness. So far in the 2017 Coastal Master Plan process, this functionality has not been deemed necessary to use.

2.5.3.4 Optimization Outputs

For each alternative, the Planning Tool defines the projects to implement and estimates the expected outcomes coast wide with respect to key metrics for each alternative.

Expected outcomes for restoration alternatives are calculated using an additive assumption, per the following formula:

$$Expected\_outcome_{m,t,r} = FWOA_{m,t,r} + \sum_p offset\_effect_{p,m,t,r}$$

where *FWOA* is the future without action outcome; m is a specific ecosystem metric (e.g., land); t = time slice (e.g., year 10); r = region; p = selected restoration projects from the alternative. The *offset_effect* for metric, m, is the restoration project effect offset by the implementation period defined for each specific project, p, time slice, t, and region, r (see Section 2.5.3.2 and Table 8, above).

For risk alternatives, expected outcomes are calculated as:

$$Expected\_outcome_{m,t,r} = FWOA_{m,t,r} + \sum_p Effect_{p,m,t,r}$$

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[13] In testing of this method using 2012 data, a value slightly larger than 0 was used to exclude projects that exhibited no or declining land effects between 2040 and 2050.

where *FWOA* is the future without action outcome; *m* is a specific risk metric (e.g., EAD); *t* = time slice (e.g., year 10); *r* = region; *p* = selected risk reduction projects from the alternative.

The expected outcome calculation is performed only for those metrics that have FWOA values and can be reasonably assumed to be additive. As outputs are generated, whether or not they are additive will be assessed and stored in the Planning Tool database.

Interactive visualizations show comparisons of the projects selected and the estimated outcome across the alternatives, as described in Section 2.5.5.

2.5.4 Evaluating Alternatives

2.5.4.1 Comparing Alternatives of Different Specifications

The Planning Tool helps CPRA to compare different alternatives through visualizations that compare:

- Project selection across implementation periods
- Expected outcomes

Section 3.4, below, presents the results from this step.

2.5.4.2 Defining the Draft and Final Master Plan

CPRA, in consultation with stakeholders and management are using the analysis from the Planning Tool to help develop the Draft Master Plan (in the Fall or 2016) and the Final Master Plan (in the Winter of 2016/2017). Section 3.4.5 describes how CPRA used Planning Tool results along with additional information to define the draft master plan.

2.5.5 Supporting Deliberations

The Planning Tool analyses, described above, are by their nature exploratory and do not present simple conclusions. Projects are numerous and can be compared across different metrics, regions, and time periods. Alternatives are comprised of different combinations of projects and have differential effects across the coast. The Planning Tool, thus, helps CPRA and stakeholders explore the analytic results, see the key differences, and support deliberations through interactive visualizations and iteration (Figure 18).

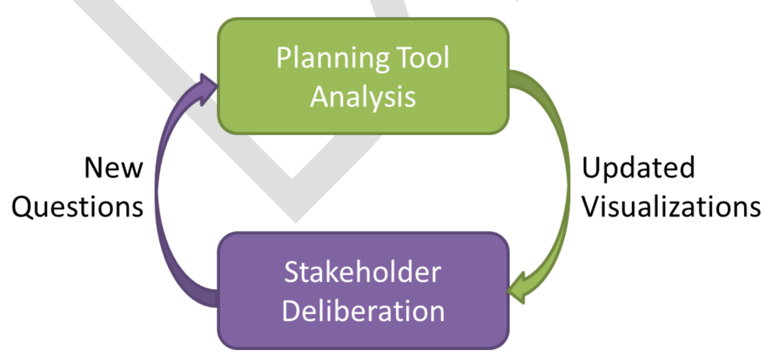

Figure 18: Deliberation with Analysis.

The Planning Tool's visualizations are developed using Tableau, a business analytic data analysis and visualization platform.[14] Tableau connects directly to the Planning Tool SQLite database and provides a flexible interface to develop custom interactive graphics. The visualizations are packaged in workbooks and made available via a website. Figure 19 shows the welcome screen for the 2017 Planning Tool.

Figure 19: 2017 Planning Tool Welcome Screen.

Through this iteration, new questions are asked of the Planning Tool, which then is used to develop new analyses and updated visualizations. As described in Section 3.0, CPRA is conducting multiple iterations of this process to develop the 2017 Coastal Master Plan.

3.0 Planning Tool Analyses for 2017 Coastal Master Plan

This report describes the Planning Tool analysis performed for the 2017 Coastal Master Plan through the end of September 2016. It begins describing Planning Tool summaries of the Future Without Action conditions (section 3.1). Next, section 3.2 summarizes the nonstructural project variants developed using the Planning Tool. Section 3.3 then compares the risk reduction and restoration projects based on Planning Tool estimated outcomes and cost effectiveness metrics. Section 3.4 provides descriptions of the alternatives analysis performed, leading up to the Draft Master Plan (section 3.5).

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[14] Details on Tableau can be found at the developer's website: www.tableausoftware.com.

Each section includes a brief overview and then follows with a listing of key questions that were posed prior to each analysis and description of the performed analysis and deliberations. The sections end summarizing the key results. The figures shown are generated by the Planning Tool and together provide an overview of how the Planning Tool visualizations supported the analytic process.

3.1 Future Without Action Conditions

The 2017 analysis began by establishing a set of baseline outcomes for the FWOA conditions. This section describes some key observations of these results as shown in the Planning Tool.

3.1.1 Key Questions, Analysis, and Deliberation

- What is the range of projected coastal land loss over the next 50 years across the environmental scenarios without new investments or management?
- What is the range of projected flood risk across the coast over the next 50 years across the risk scenarios without new investments or management?
- What other key environmental and infrastructure assets are at risk?

The Planning Tool includes summaries of how ecosystem conditions and risk could change over the coming 50 years under three different environmental scenarios. These visualizations were shared with CPRA management, stakeholders, and various advisory groups.

3.1.2 Results for restoration metrics

Over the 50-year simulation period, coast wide land declines from about 16.3 thousand km^2 to 11.7 thousand km^2 (for the Low environmental scenario), to 9.0 thousand km^2 (for the Medium environmental scenario), and to 5.3 thousand km^2 (for the High scenario) in year 50 (Figure 20). These results reinforce concerns about continued land loss, while also highlighting the significant uncertainty over how quickly land loss could occur.

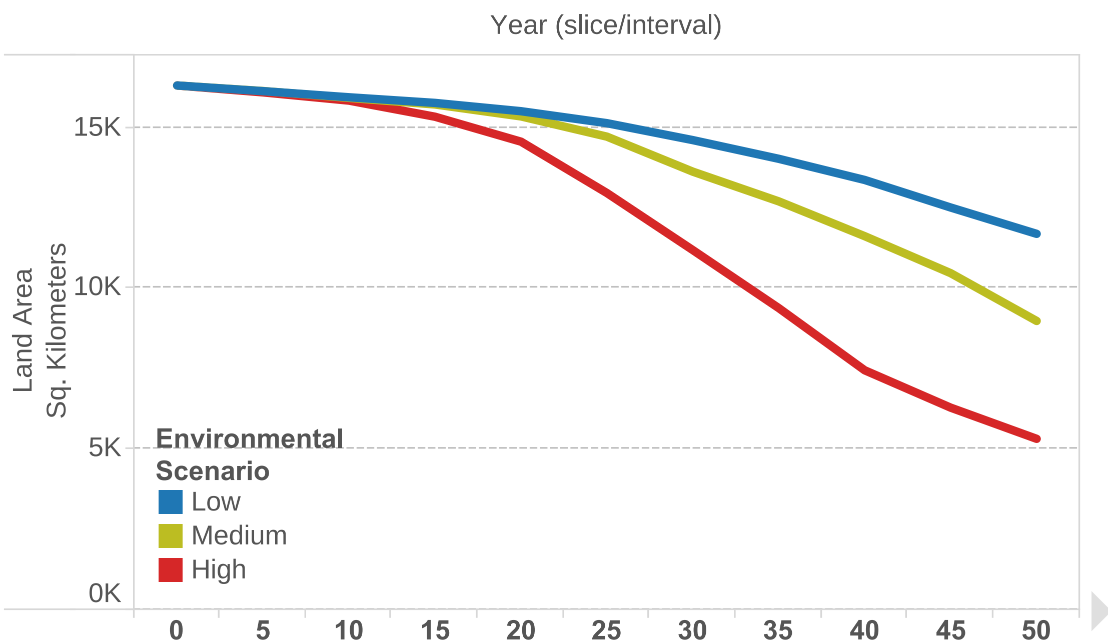


Figure 20: Coast Wide Change in Future Without Action Land Area for Three Environmental Scenarios.

Outcomes for other metrics were reviewed as well. CPRA discussions with stakeholders focused on the following metrics: freshwater wetlands, brown shrimp habitat, white shrimp habitat, and mottled duck. Figure 21 shows Freshwater Wetlands and juvenile Small Brown Shrimp habitat over time for the three environmental scenarios under Future Without Action conditions. For all three scenarios, freshwater wetland area declines significantly. In contrast, habitat for Brown Shrimp increases modestly in all scenarios.

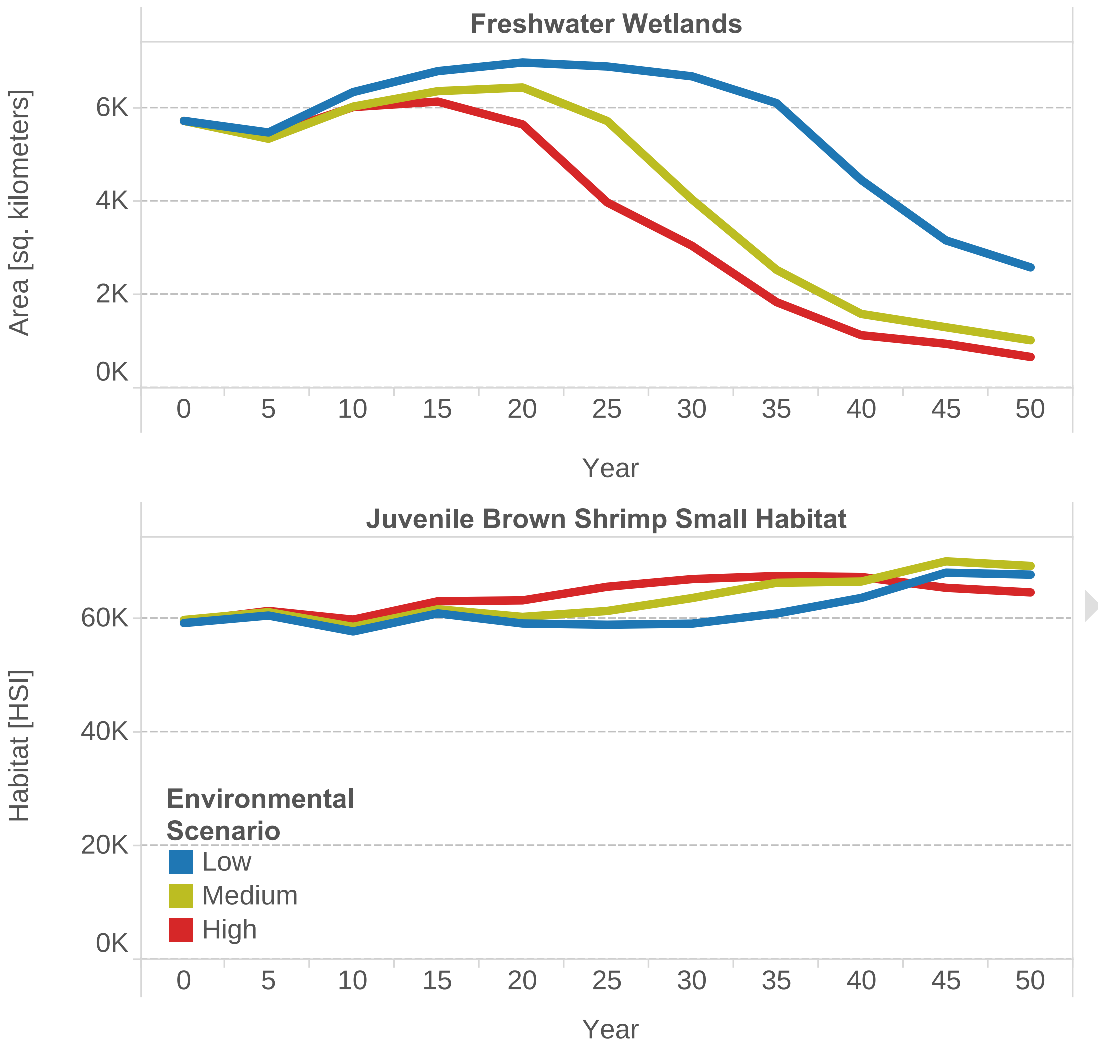


Figure 21: Coast Wide Change in Future Without Action Freshwater Wetlands and Juvenile Small Brown Shrimp over time.

3.1.3 Results for risk metrics

The 2017 model simulations project large increases in storm surge/wave flood risk, represented by expected annual damage at years, 10, 25 and 50. The modeling results show significant variation across the environmental scenarios as well. For example, risk is estimated to increase from $2.7 B in the initial condition to $6.7 B in year 50 for the Low environmental scenario, but to $19.9 B for the High environmental scenario (Figure 22).

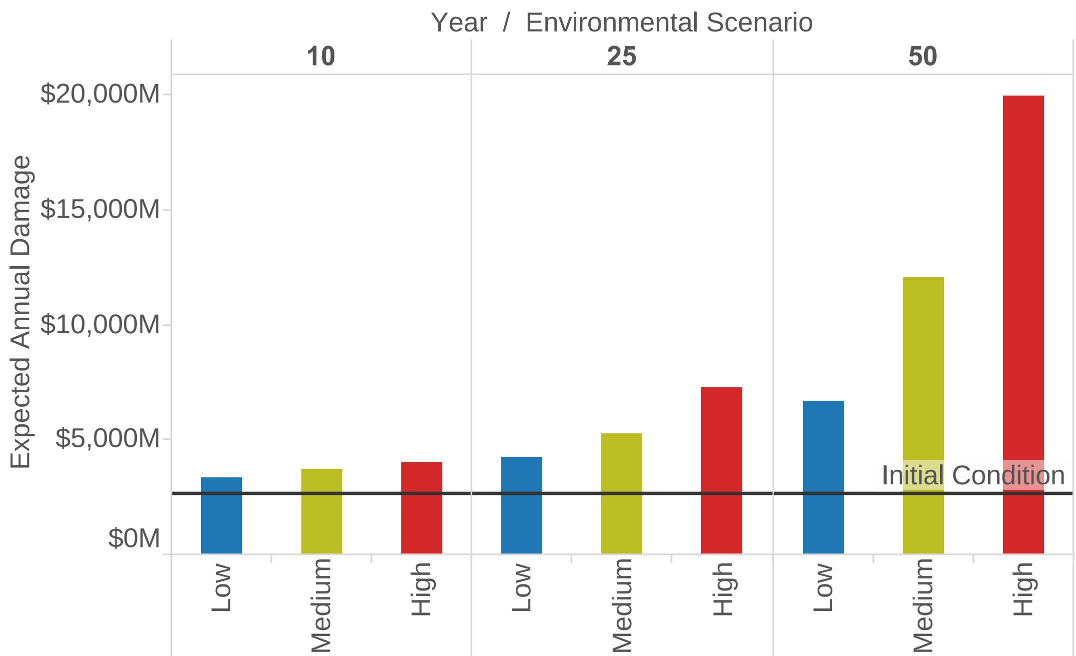


Figure 22: Coast Wide Change in Future Without Action Expected Annual Damage Across Three Environmental Scenarios Over Time.

Two regions with the greatest risk under the Low scenario are the Terrebonne region, which includes the city of Houma, and St. Tammany, which is on the North shore of Lake Pontchartrain (Figure 23). Under the High scenario additional regions show high risk—Lafourche, St. Charles, Jefferson, and New Orleans. Under this scenario, existing structural risk reduction does not prevent extensive flooding under surge events.

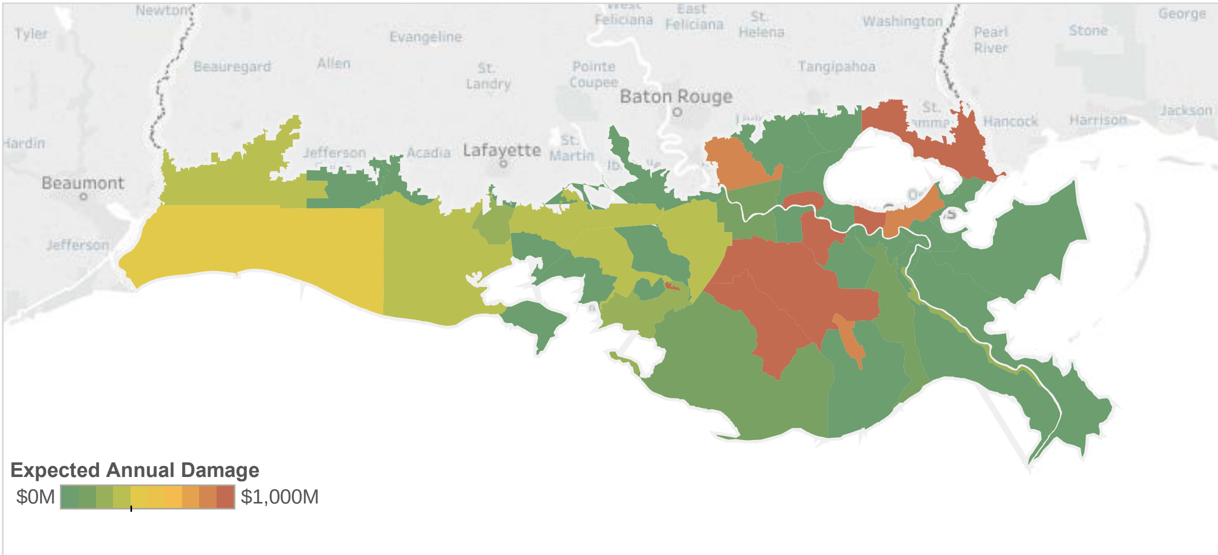


Figure 23: Spatial distribution of Changes in Expected Annual Damage by Year 50 in Future Without Action for High Environmental Scenario.

The Planning Tool also reviewed risk results across three different fragility scenarios and growth scenarios (see Attachment C3-25 – Storm Surge and Risk Assessment). To date, CPRA has focused on differences across the environmental scenarios for the IPET fragility scenario and historical growth scenario only.

3.2 Formulating Nonstructural Projects

As described in 2.5.1, the Planning Tool helped CPRA develop seven different nonstructural project variants for each of the 54 risk regions. Each variant differed based on the elevation standard used to define mitigations. In one case, an additional constraint was added to only include regions with high low-to-moderate income households. This section describes how developing these variants helped CPRA determine which to include in the alternative formulation analysis.

3.2.1 Key Questions, Analysis, and Deliberations

- How much and what type of nonstructural mitigation is required based on a range of different flood elevation standards?
- How much would it cost to mitigate all eligible areas of the coast to the different flood elevation standards?
- Which nonstructural project variants should be evaluated in alternative formulation?

To address these questions, CPRA reviewed the results of costs and mitigations for each variant to determine how best to consider nonstructural projects in the alternative formulation analysis, described in section 3.4.

3.2.2 Results

Figure 24 shows the results for the seven nonstructural project variants with respect to the number of structures (top row), mitigation costs (middle row), and EAD reduction in year 25 for the High environmental scenario (bottom row). The colors denote the asset type. The number of mitigations increases from Variants 1 through 7, with the exception of Variant 5 that includes a constraint that focuses only on high low-to-moderate income properties. Figure 32 also shows that most mitigations (in terms of number of structures) affect single family and manufactured homes. The bottom row of the figure, however, shows that the much smaller number of commercial property mitigations accounts for a large share of the total risk reduction.

Figure 24: Coast Wide Summary of Costs and Mitigations for Seven Nonstructural Project Variants.

Figure 25 shows the number of structures (length of vertical bars) that would be floodproofed, elevated, and acquired coast wide (rows) for each of the seven variants (columns). The coloring shows the share of structures by asset type. The vast majority of mitigations are elevations—between 14,600 and 43,500. The number of large multi-family homes and commercial properties that are floodproofed is much lower—ranging from about 900 to 1,700.

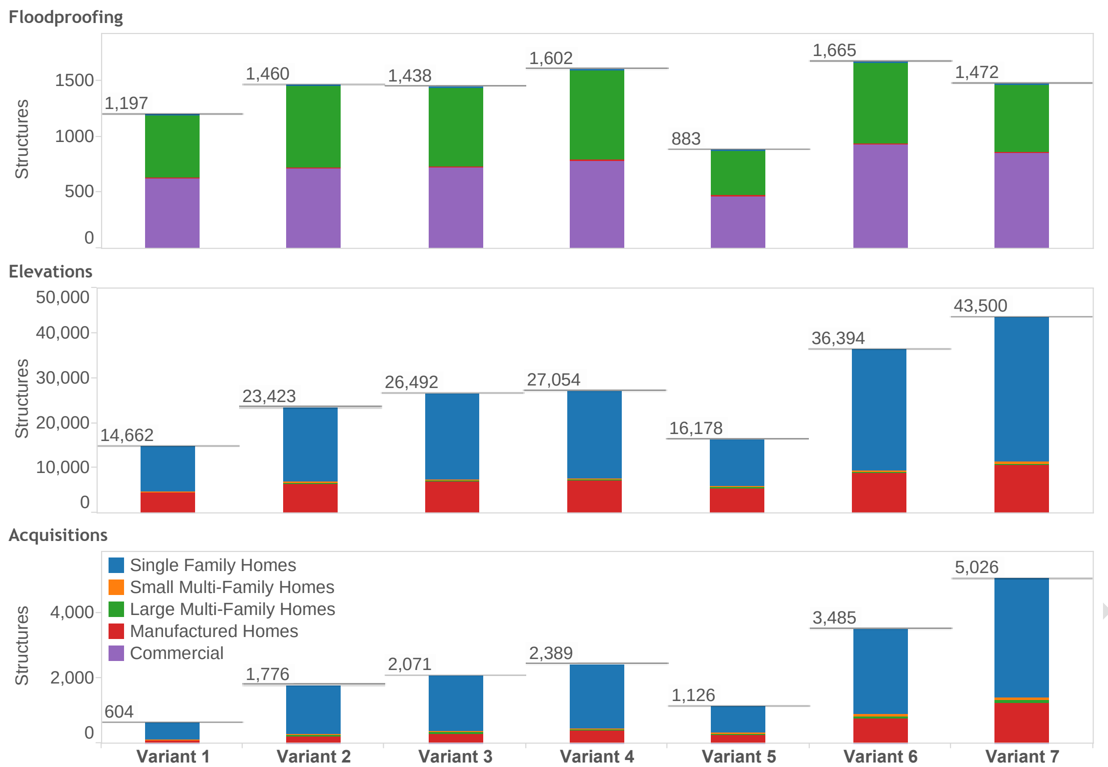


Figure 25: Coast Wide Summary of Mitigations for Seven Nonstructural Project Variants.

CPRA decided to formulate alternatives using nonstructural project variants 4 and 7, which are based on the High environmental scenario. Figure 26 shows the relative number of structures by nonstructural project area that would be mitigated for project variant 4 and variant 7. For reference, the areas with the most structures for variant 4 (as shown in Figure 25) are:

- St. Tammany (STT.01N): 5,802 structures
- Terrebonne – Houma (TER.02N): 5,768 structures
- St. Charles – Hahnville/Luling (STC.01N): 3,198 structures
- Lafourche – Raceland (LAF.03N): 1,512 structures
- Plaquemines – West Bank (PLA.01N): 1,409 structures
- Jefferson – Lafitte/Barataria (JEF.02N): 1,267 structures
- St. John the Baptist – Laplace/Reserve (SJB.01B): 1,238 structures

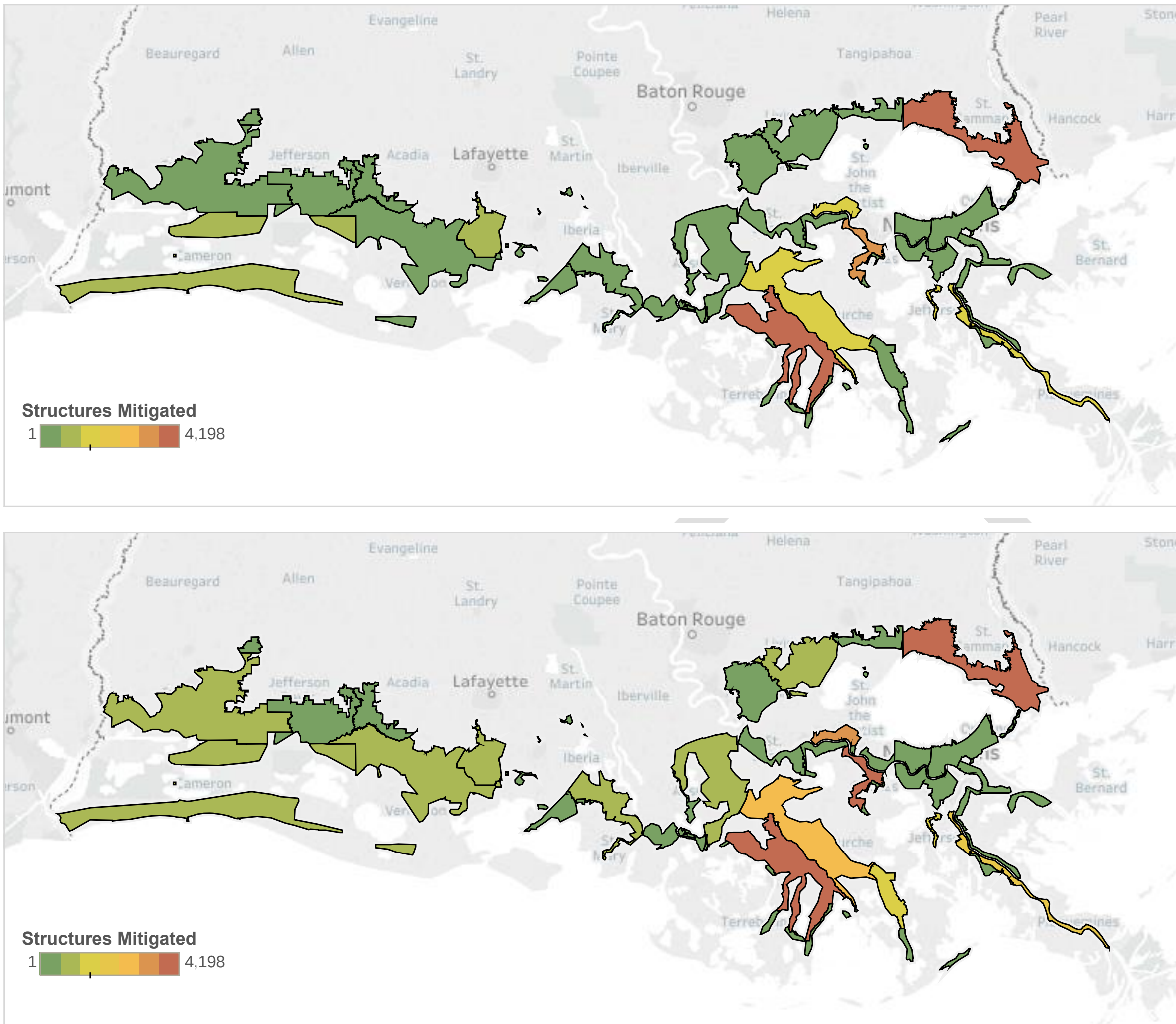


Figure 26: Relative Number of Structures Mitigated Across the Coast for Nonstructural Project Variant 4 (top) and Variant 7 (bottom).

3.3 Comparison of Individual Projects

CPRA developed attribute information, including costs, for all projects and provided those data to the Planning Tool. The systems models estimated for each individual project, the effects of the individual projects with respect to the ecosystem metrics and risk metrics. The Planning Tool used these data to compare individual projects.

3.3.1 Key Questions, Analysis, and Deliberation

- How do risk reduction projects rank with respect to mid-term and long-term risk reduction cost-effectiveness? How do the rankings change under different scenarios?
- How do restoration projects rank with respect to near-term and long-term land building cost-effectiveness? How do the rankings change under different scenarios?
- How do structural and nonstructural projects compare in terms of benefits?

- How does the effect of the restoration projects change over time under different scenarios?

The Planning Tool calculated project cost effectiveness for key metrics and presented visualizations showing how projects compare based on effects, including change over time, and cost effectiveness. The project team and CPRA reviewed these results to understand which projects would likely provide benefits desired for the master plan.

3.3.2 Risk Reduction Project Results

The Planning Tool compares risk reduction projects based on mid-term and long-term reduction in EAD. Figure 27 shows that many structural projects—Morganza to the Gulf, Lake Pontchartrain Barrier, Upper Barataria Risk Reduction, West Shore Lake Pontchartrain, Slidell Ring Levees, Larose to Golden Meadow, and the Greater New Orleans High Level—provide substantial risk reduction, as compared to the individual nonstructural projects, for the three environmental scenarios (only results for the High environmental scenario and NS project variant 4 are shown). The structural projects generally reduce risk more for the Medium and High environmental scenarios—the worse the conditions are, the more benefit the projects provide. The other structural projects reduce risk much less, as do the nonstructural projects. Lastly, risk reduction is greatest for NS variants 4 and 7, due to elevating to the higher recommended 100-year flood depth (above grade) plus two feet of freeboard.

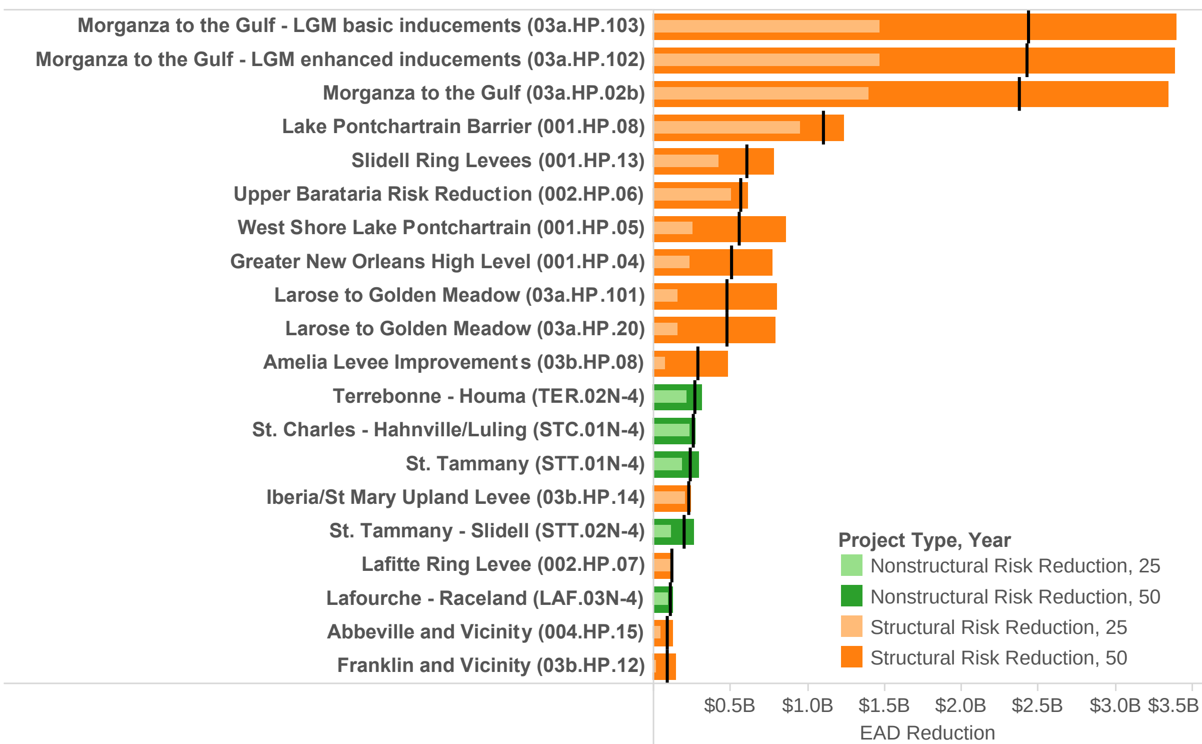


Figure 27: Expected Annual Damage Reduction in year 25 and 50 for the High Environmental Scenario for the Top 20 Risk Reduction Projects (Only Nonstructural Project Variant 4 is Shown).

In terms of cost effectiveness, many nonstructural projects perform better than the structural projects in all scenarios, due to their relatively lower costs. Nonstructural projects with high cost effectiveness include those in St. James – Vacherie, St. Mary – Morgan City, and Ascension – Prairieville/Sorrento, although these projects are small and involve only a few structures. The

Slidell Ring Levee structural project is the most cost effective risk reduction project under the high scenario (Figure 28). The most expensive structural projects—Morganza to the Gulf and Lake Pontchartrain Barrier—are less cost effective than many nonstructural projects. However, they are the only projects evaluated by the Master Plan that significantly reduce risk in many regions, as shown in Figure 29.

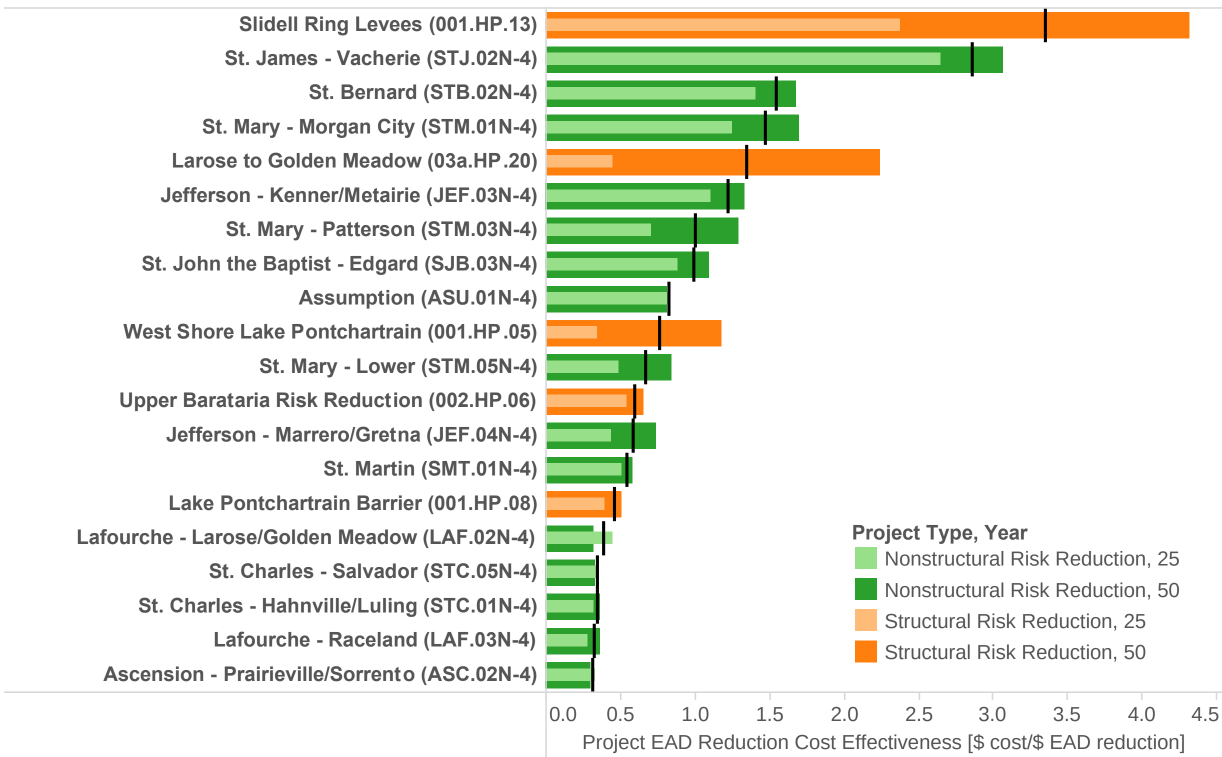


Figure 28: Expected Annual Damage Cost Effectiveness in Year 25 and 50 for the High Environmental Scenario for the Top 20 Risk Reduction Projects (Only Nonstructural Project Variant 4 is Shown).

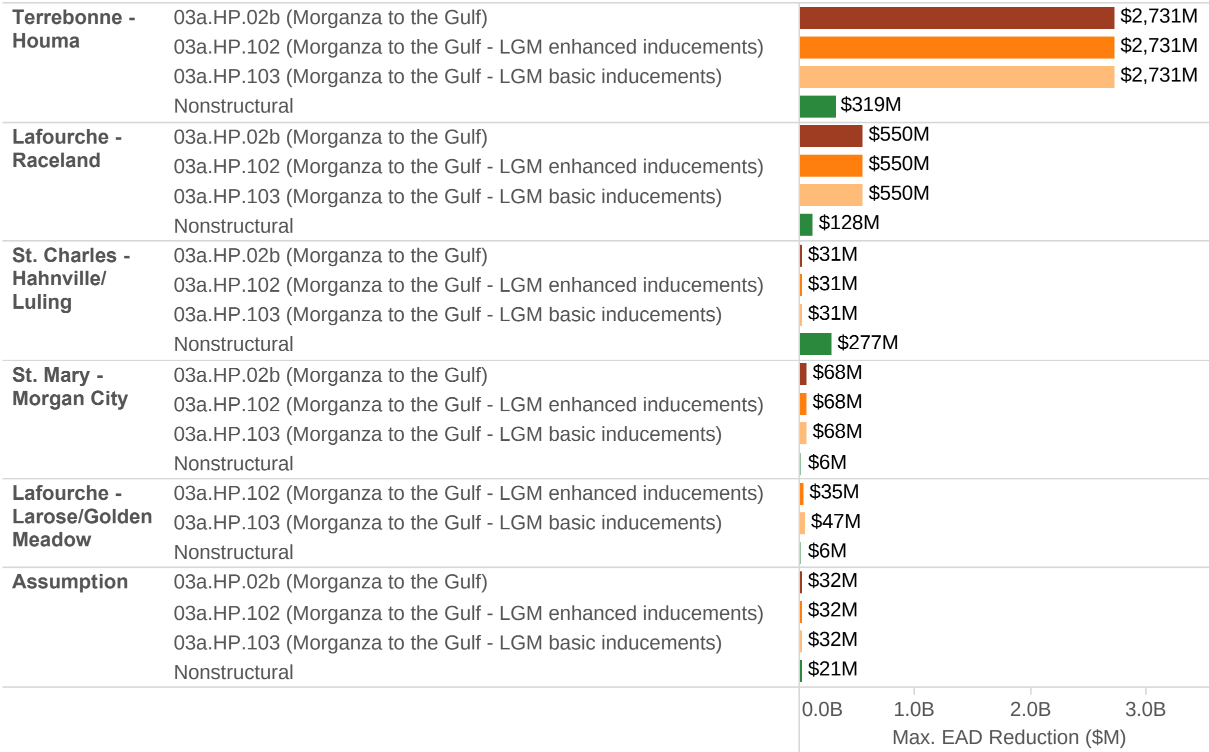


Figure 29: Expected Annual Damage Reduction in Year 50 for the High Environmental Scenario for Projects Affecting the Regions in the Influence Area of Morganza to the Gulf Project (Only Nonstructural Project Variant 4 is Shown).

3.3.3 Restoration Project Results

Marsh Creation and Sediment Diversion projects lead to the largest positive land gain in the near-term (year 20) and long-term (year 50). Figure 30 shows the change in land area in year 20 and year 50 for the top 20 restoration projects. For some projects, near-term benefit is negative even when long-term benefit is positive (e.g. Upper Breton Diversion). For other projects, near-term benefit is positive while long-term benefit is negative (e.g. Belle Pass-Golden Meadow Marsh Creation).

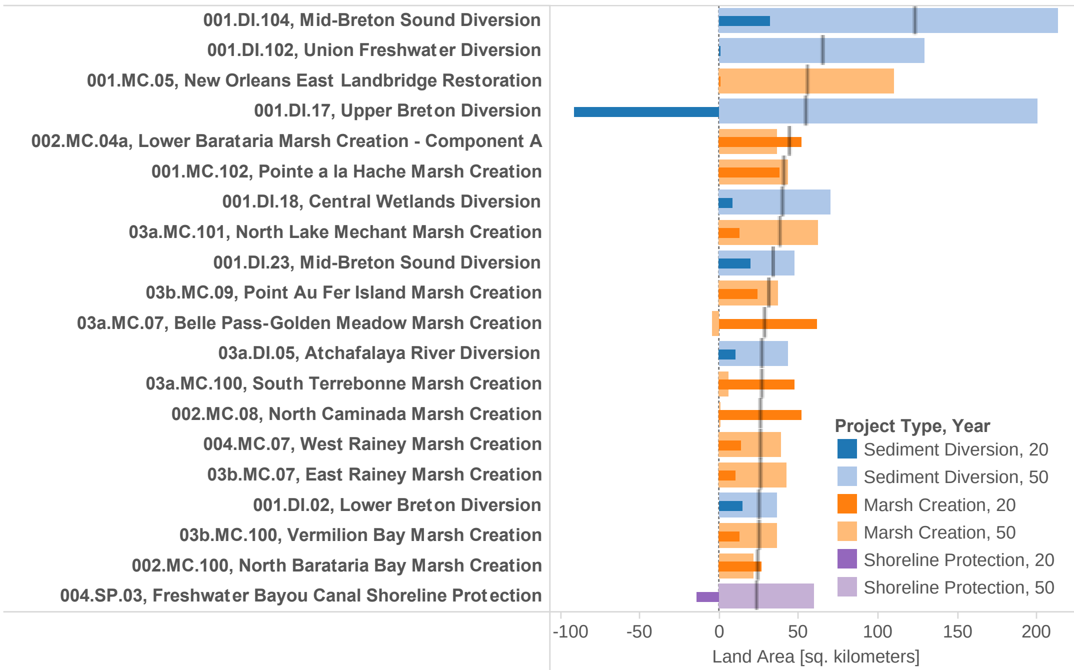


Figure 30: Near-term (Year 20) and Long-term (Year 50) Land Area Project Effects for Top 20 Restoration Projects for the High Environmental Scenario.

The Planning Tool shows the effects of each restoration project on land (and other metrics) over time for each scenario. Figure 31 shows these results for two restoration projects, assuming implementation in period 1. The first project—Belle Pass-Golden Meadow Marsh Creation—would lead to large increases in land by year 20. These benefits persist under the Low and Medium scenario, but are lost by year 50 under the High environmental scenario. The second project—Mid-Breton Sound Diversion—shows gradually increasing benefits under all scenarios, yet the increase is more rapid under the High environmental scenario.

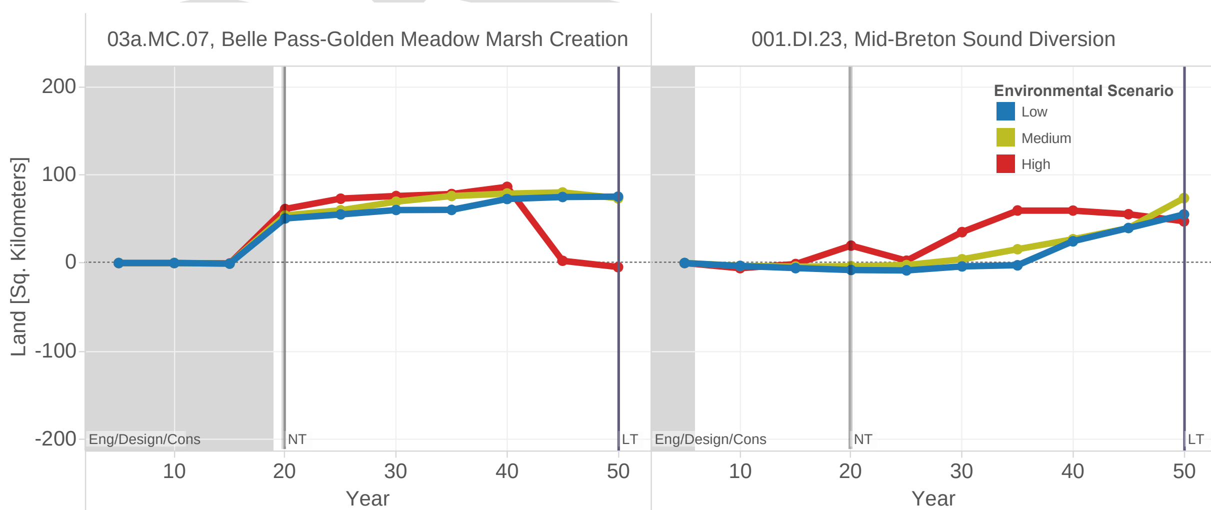


Figure 31: Project Effect on Land Over Time For Two Restoration Projects Implemented in Period 1, Under Three Environmental Scenarios.

Figure 32 illustrates how estimated benefits at the near-term time slice (year 20) and long-term time slice (year 50) change when the Planning Tool selects projects to be implemented in later periods. For the Belle Pass-Golden Meadow Marsh Creation project, delaying implementation by 10 years eliminates the near-term benefits due to the long engineering, design, and construction time, but also leads the project to persist through year 50 for all three scenarios. For the Mid-Breton Sound Diversion project, near-term benefits are slightly negative and long-term benefits are lower for the Low and Medium environmental scenario than for the High environmental scenario.

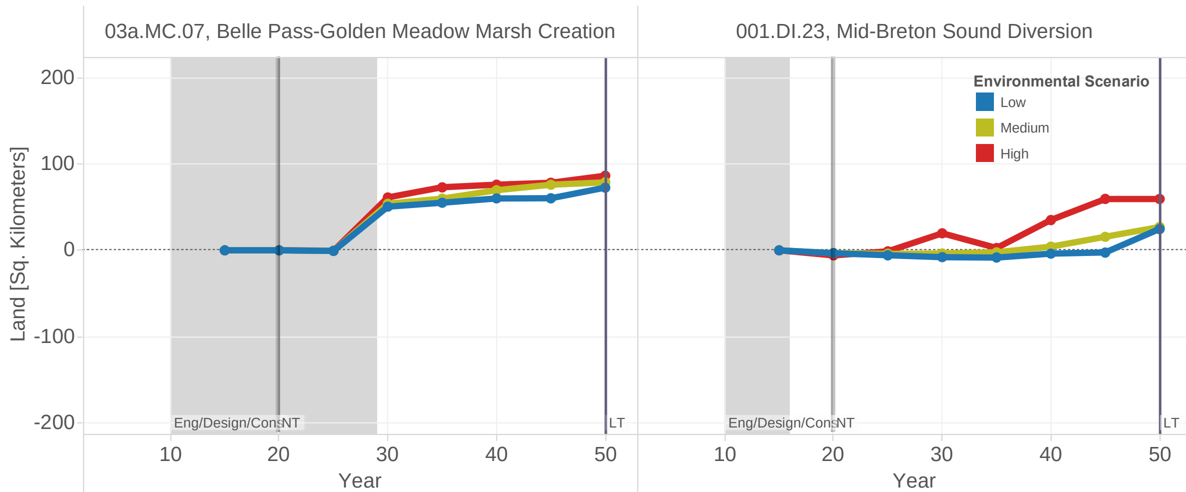


Figure 32: Project Effect on Land Over Time For Two Restoration Projects Implemented in Period 2, Under Three Environmental Scenarios.

When considering cost effectiveness (the project effect divided by total project cost), however, a mixture of project types was identified to be the most cost effective (Figure 33).

Figure 33: Near-term (Year 20) and Long-term (Year 50) Project Land Cost Effectiveness Under the Medium (left) and High (right) Scenario for Top 20 Restoration Projects for the High Environmental Scenario.

3.4 Alternative Formulation

The Planning Tool team has developed numerous alternatives for consideration by CPRA and stakeholders. The alternative formulation process has roughly followed the interrelated steps shown in Figure 34. Key questions posed by CPRA or stakeholders inform the development of new instructions or specifications for the Planning Tool. The Planning Tool is then used to develop new alternatives, which are then reviewed and used to support deliberations over outcomes and project selections. Importantly, the figure indicates that this process is iterative and is informed with improved data as it becomes available.

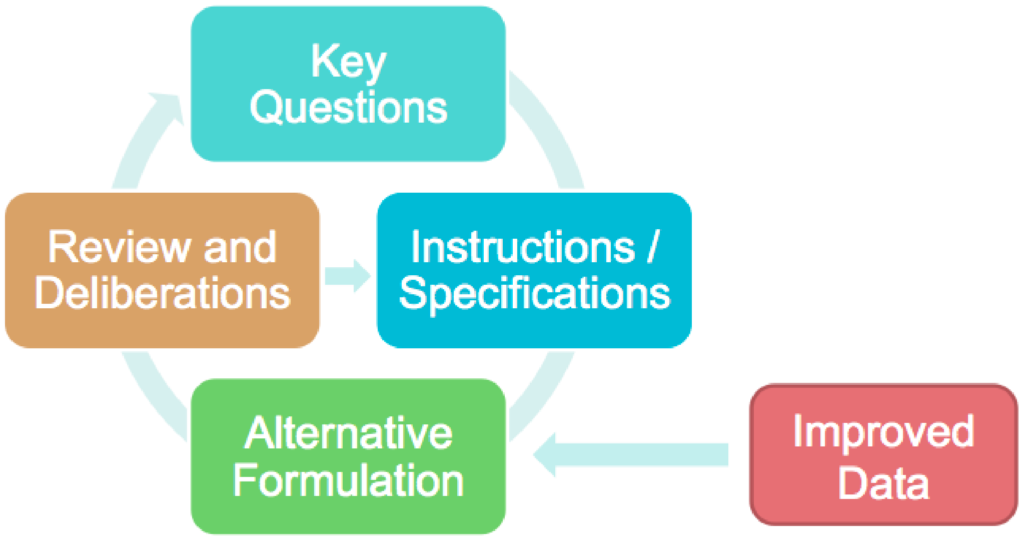


Figure 34: Overview of Alternative Formulation Process.

Figure 35 shows how the alternative formulation process shown in Figure 34 has produced sets of alternatives leading up to the formulation of the draft master plan. The remainder of section 3.4 begins with a description of improved data (section 3.4.1). It then describes several rounds of alternative formulation (sections 3.4.2 – 3.4.4). Lastly, it shows results from evaluations of select alternatives using the systems model (section 3.4.5). Section 3.5 then presents the Draft Master Plan.

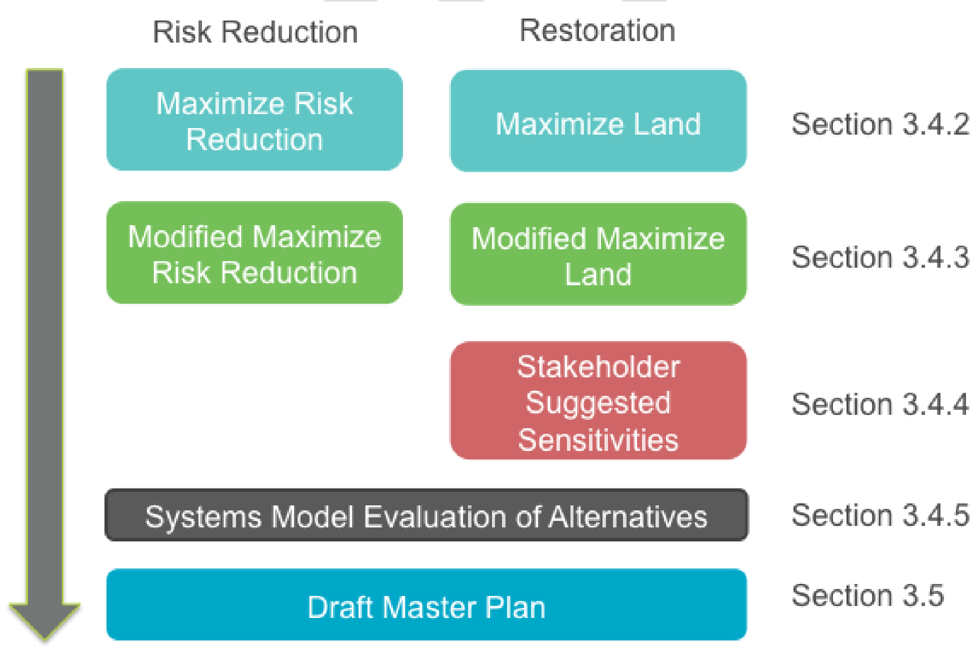


Figure 35: Formulated Alternatives Leading up to the draft master plan.

3.4.1 Improved Data

During the FWOA and project level analysis, the modeling team identified several unexpected responses in landscape conditions. This led to adjustments to the ICM code and, in some instances, changes in project specifications to account for changing coastal conditions over time. The main adjustments are outlined here with an emphasis on how they were incorporated into the Planning Tool analysis. Further details can be found in the detailed reports Integrated Compartment Model (ICM) Development (Attachment C3-22) and ICM Calibration, Validation, and Performance Assessment (Attachment C3-23). Many of the changes described here occurred between project and alternatives level analysis in the ICM. The Planning Tool ingested data as it became available, and the model version and project changes were tracked. Concurrently, a switch from CLARA reporting 50th percentile EAD to mean EAD and reevaluations using the updated FWOA landscape conditions were made, leading to improved but different risk results over time. As such, alternatives described in this section are either based on the original version of the ICM and CLARA models (denoted model version 1) or on a later version of the models (denoted model version 3).

3.4.1.1 Revisions to the ICM

After completing several multi-decadal model runs under a variety of environmental scenarios, it became clear that several aspects of the ICM required adjustment to ensure appropriate response to changing environmental conditions. The changes described here were implemented in the ICM upon the completion of the project-level runs. Selected projects in areas most heavily impacted by the model changes were rerun with model version 3, including those in the Upper Pontchartrain Basin (i.e., Union Diversion) and western Terrebonne (i.e., Increase Atchafalaya Flow). All model runs of alternative plans (section 3.4.5) and the draft plan were completed with the following updates included in the ICM. A revised FWOA condition using model version 3 of the ICM was also generated to assure consistency with project effects.

Specific changes are documented here:

- Due to changing hydraulic conditions during later decades, some ICM-Hydro compartments that performed well during the calibration period were subject to some instabilities in salinity calculations. A re-calibration effort was undertaken to improve salinity calculation stability during later decades. This adjustment changed salinity patterns particularly in upper basin areas and influenced the change in land-water in those areas as well as the extent of freshwater wetlands.
- It became apparent that the originally specififed 'threshold approach' for dead floating marsh in the ICM-Morph subroutine was not adequately capturing the floating marsh dynamics. A new methodology was developed using an approach that progressively removes dead 30 m floating marsh pixels within each 500 m grid cell. While floating marsh is not tracked specifically in the Planning Tool, this adjustment influenced the change in land-water in areas of floating marsh and thus the extent of freshwater wetlands.
- Due to rapidly increasing salinity in later years of the 50-year model simulation, the vegetation dynamics occasionally predict large areas of bare ground. Due to a lack of vegetation type in bare ground areas, the ICM-Morph subroutine would not apply collapse criteria to this land. To correct for this, a new collapse threshold was added to the ICM-Morph algorithms, allowing for bare ground that was inundated for two

consecutive years to collapse into open water. Prior to this adjustment, areas of bare ground endured for long periods in the later years of the 50 year simulations. This adjustment resulted in changes in land-water patterns within many basins.

In summary, the development of version 3 of the ICM means that Panning Tool analysis using model version 1 should not be directly compared with either FWOA or alternatives analyzed using model version 3.

3.4.1.2 Adjustments in Project Specifications

Many projects were modeled based on fixed assumptions about characteristics or operations which reflect current approaches but do not take into account changes in the future conditions. Two specific changes are described below:

- **Low Flow Operation of Sediment Diversion projects**. The operation regimes for sediment diversion projects were defined prior to the project level runs, and they were based on current operational considerations. All sediment diversion projects were modeled with the assumption that there would be zero flow when the discharge in the Mississippi River falls below 5,660 cubic meters per second (cms). The river hydrograph used for the 50-year simulations is an actual record of river flow from 1964-2013. This includes several years when flow declines below that threshold for weeks to months. Inspection of project level runs for several of the sediment diversion projects showed that the diversions were keeping large areas of the basins fresh for much of the year when operating, supporting extensive freshwater wetlands. However, during a single year when the diversion was turned off due to low flow, the salinity increased resulting in loss of freshwater wetlands. Such a 'shock to the system' could be managed operationally to avoid such consequences, and it seemed as if the strict model assumptions were predicting conditions that would actually be avoided by on the ground decision-making. Thus two sediment diversion projects, Mid-Barataria and Mid-Breton were adjusted to ensure that during low river discharge a minimum flow of ~140cms was maintained. To address this issue for the Planning Tool analysis, these two projects were reanalyzed using the updated operations, and the outcomes of the reanalysis were made available to the Planning Tool for selection during the modified runs.
- **Construction Elevation for Marsh Creation Projects**. In the project level runs, marsh creation projects were placed on the landscape to a fixed elevation relative to NAVD88 for all areas meeting the fill depth criteria (Appendix A – Project Definitions). This elevation was based on current construction practice. The Planning Tool received updated information for all marsh creation project increments indicating the amount of sediment (and this cost) to meet this elevation requirement in all three implementation periods per environmental scenario and information about the amount of land that could be built for each period/scenario. In later periods and higher scenarios, especially in areas with high subsidence rates, the marsh built using these specifications was sometimes so low in the tidal frame that it did not endure following construction. An adjustment was made following the project level analysis to implement projects by adjusting the marsh creation construction elevation to account for sea level rise and subsidence. All alternatives, draft plan, and final plan runs included these modified assumptions on initial construction elevation. As a result, the change in approach to

construction elevation means that marsh creation projects modeled by the ICM as part of alternatives may endure longer and have different near-term and long-term land benefits than the individual project increments modeled during the project level runs.

As most of the changes described here were implemented in the alternatives testing phase of the Planning Tool analysis, within any single analysis, all projects are being compared or analyzed on the same basis.

3.4.1.3 Example differences due to modeling changes

Figure 36 shows coast wide land area under FWOA conditions for the two model versions. The largest difference in model version 3 results is the less rapid land loss in the middle years of the simulation.

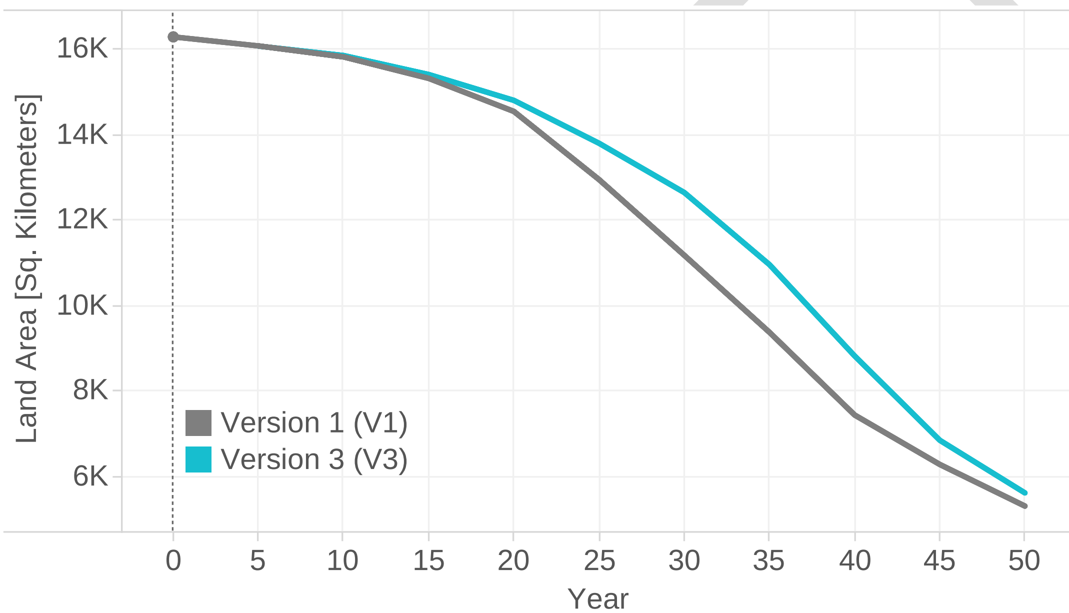
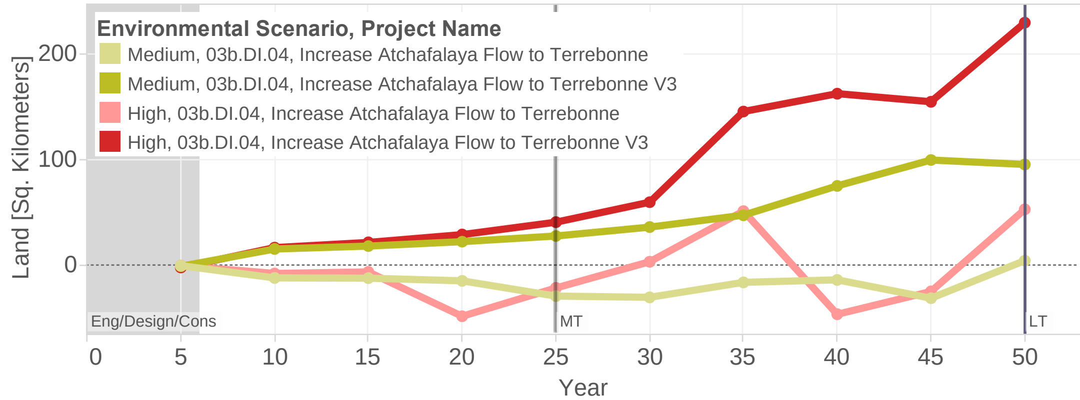


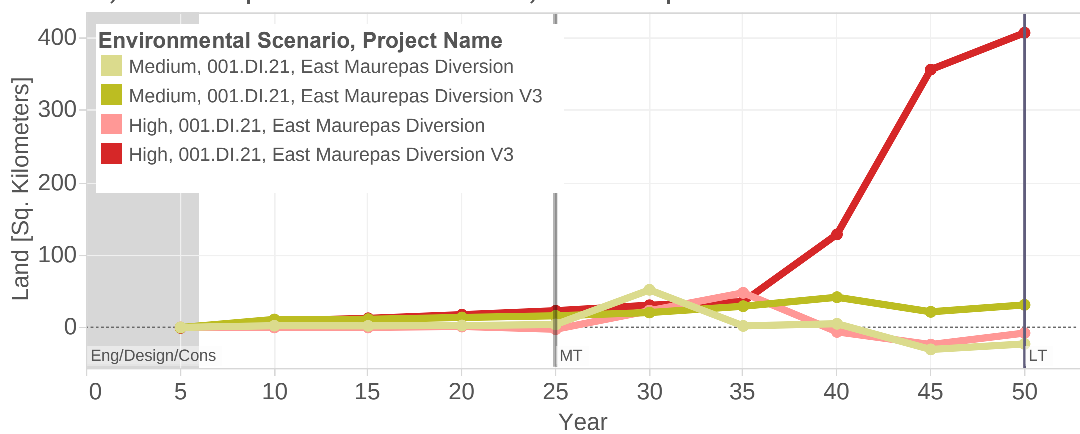
Figure 36: Land Area for Future Without Action Conditions for Version 1 and Version 3 of the ICM.

The modeling improvements also affect the performance of sediment diversion projects, for example. Due to time constraints, not all diversion projects were reevaluated using model version 3, only three projects were reevaluated —Increase Atchafalaya Flow to Terrebonne, East Maurepas Diversion, and Union Freshwater Diversion. As Figure 37 shows, the version 3 modeling of these projects shows significantly more land building, particularly for the High environmental scenario. As shown in later sections, these projects lead to different project selection by the Planning Tool. For example, under model version 1, these three projects show low or negative average near-term/long-term benefits for the High environmental scenario. Under model version 3, the benefits in the High environmental scenario are estimated to be strongly positive. The new versions of the Mid-Barataria Diversion (002.DI.102) and Mid-Breton Sound Diversion (001.DI.104) projects that include a minimum flow of ~140 cms under low Mississippi River flow conditions (as described in Section 3.4.1.2) projects were also developed and added at this stage of the analysis.

03b.DI.04, Increase Atchafalaya Flow to Terrebonne & 03b.DI.04, Increase Atchafalaya Flow to Terrebonne V3



001.DI.21, East Maurepas Diversion & 001.DI.21, East Maurepas Diversion V3



001.DI.102, Union Freshwater Diversion & 001.DI.102, Union Freshwater Diversion V3

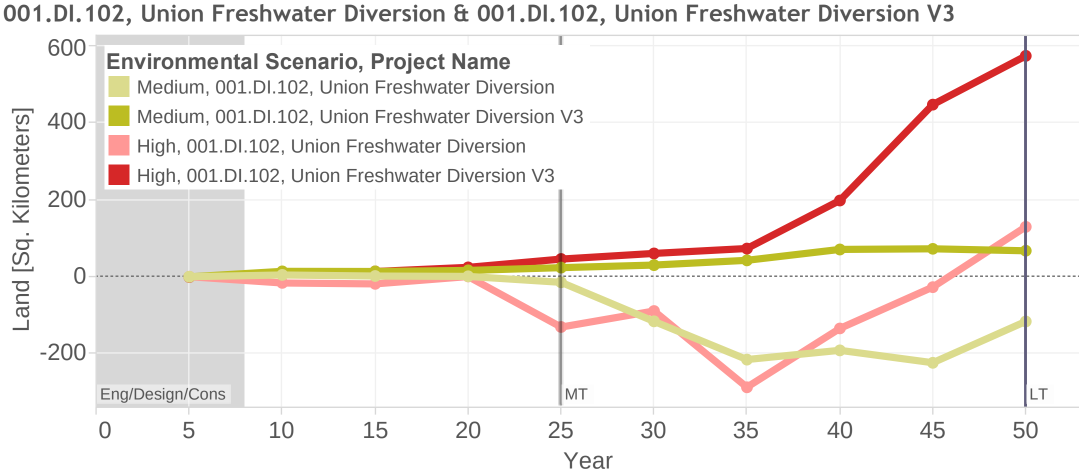


Figure 37: Projected Land Area for Three Diversion Projects by Version 1 and Version 3 of the ICM for the Medium and High Environmental Scenarios.

3.4.2 Maximize Risk Reduction and Maximize Land

The first set of alternatives explores project selection and outcomes across different funding levels and environmental scenarios. These alternatives provided CPRA with preliminary estimates (based on individual project effects) of how much risk could be reduced and how much land loss could be reduced. Exploring how these results vary across different funding levels and environmental scenarios helped CPRA focus on a single funding level ($25B for risk reduction projects and $25B for restoration projects) and environmental scenario for subsequent alternatives.

3.4.2.1 Key Questions, Analysis, and Deliberation

- Which projects are always selected across different funding and environmental scenarios?
- How does project selection change across funding scenarios?
- How much can future land loss be reduced with different funding levels under different environmental and funding scenarios?
- How much 50-year risk can be reduced under the environmental, risk, and funding scenarios?
- Which projects are selected in the first implementation period for most or all the environmental and risk scenarios for a given funding scenario (i.e., low-regret period 1 projects)?
- Are the projects selected under scenarios with larger funding inclusive of those selected with less funding, or are different projects selected when funding is greater? Which project decisions are driven solely by available funding?

The Planning Tool developed many different alternatives by maximizing risk reduction and maximizing land for different combinations of risk reduction and restoration funding scenarios and the three environmental scenarios—Low, Medium, and High (Table 9).

Table 9: Specifications for Maximize Risk Reduction and Maximize Land Alternatives.

Alternative Sets	Objective Function	Funding Scenarios	Environmental Scenarios	Other Constraints
Maximize Risk Reduction	Maximize EAD Reduction	$17.6B: $11.6B (years 1-30), $6B (years 31-50) $25B: $20B (years 1-30), $5B (years 31-50) $30B: $24B (years 1-30), $6B (years 31-50)	Low, Medium, and High	Only include NS Variant 4*
Maximize Land	Maximize Land Area	$22.4B: $6.4B (years 1-10), $10B (years 11-30), $6B (years 31-50) $25B: $5B (years 1-10), $15B (years 11-30), $5B (years 31-50) $30B: $6B (years 1-10), $18B (years 11-30), $6B (years 31-50)	Low, Medium, and High	

* For consistency in the nonstructural program, CPRA opted to only include Variant 4 nonstructural projects for the Maximize Risk Reduction alternatives.

The results for these alternatives are summarized below. CPRA evaluated the results for these alternatives carefully and decided to focus on the $25 billion funding level and the High environmental scenario for both risk reduction and restoration alternatives. Based on these results, CPRA then developed specifications for the Modified Maximize Risk Reduction and Modified Maximize Land alternatives (section 3.4.3).

3.4.2.2 Maximize Risk Reduction Alternative Results

The Maximize Risk Reduction alternatives include a mixture of structural and nonstructural risk reduction projects (Figure 38). Under the $25B funding alternatives, between 12 and 14 structural risk reduction projects are selected and between 28 and 37 nonstructural projects are included depending on the environmental scenario. Figure 38 also shows that under the $30B funding scenario, not all the funding is used, indicating that all projects with positive benefit are being selected.

		Structural Risk Reduction		Nonstructural Risk Reduction		Grand Total
		Period 3	Periods 1/2	Period 3	Periods 1/2	
Risk $17.6B	Low ES	4 $6,423M	10 $20,980M	6 $5,081M	40 $2,918M	60 $35,401M
	Medium ES	6 $6,704M	10 $20,980M	4 $4,809M	38 $2,941M	58 $35,434M
	High ES	8 $7,220M	10 $20,980M	18 $4,208M	22 $2,944M	58 $35,352M
Risk $25B	Low ES	14 $7,527M	14 $29,122M	10 $727M	64 $11,693M	102 $49,068M
	Medium ES	12 $9,674M	12 $28,393M		56 $12,298M	80 $50,365M
	High ES	6 $5,927M	18 $31,497M	8 $3,192M	56 $9,372M	88 $49,989M
Risk $30B	Low ES	2 $4,445M	32 $37,725M	2 $1,508M	76 $12,478M	112 $56,157M
	Medium ES	16 $4,931M	18 $36,988M	20 $1,849M	62 $12,145M	116 $55,911M
	High ES	12 $5,480M	22 $37,754M	8 $1,570M	76 $12,478M	118 $57,282M

Figure 38: Summary of Number of Projects and Total Project Costs for the Nine Maximize Risk Reduction Alternatives.

There is high level of consistency in the selection of structural projects across environmental scenarios. For the $25B funding level, all but four projects (representing less than $3 billion of the over $18 billion allocated to structural projects) are selected in both the Medium and High environmental scenario alternatives (Figure 39). One notable difference, however, is that the Lafitte Ring Levee (002.HP.07), which costs about $1.2 billion, is selected in the Medium environmental scenario, but not the High environmental scenario. This leads to differences in the selection of nonstructural projects for the two scenarios due to funding constraints.

		Maximize Risk Reduction			
		Medium ES Risk $25B		High ES Risk $25B	
Name	**Code**	Periods 1/2	Period 3	Periods 1/2	Period 3
Abbeville and Vicinity	004.HP.15				$1,511M
Amelia Levee Improvements	03b.HP.08		$1,733M		$1,733M
Bayou Chene Floodgate	03b.HP.13		$888M		
Franklin and Vicinity	03b.HP.12			$860M	
Greater New Orleans High Level	001.HP.04	$4,553M		$4,553M	
Iberia/St Mary Upland Levee	03b.HP.14		$2,684M		$2,684M
Lafitte Ring Levee	002.HP.07		$2,409M		
Lake Pontchartrain Barrier	001.HP.08	$4,819M		$4,819M	
Larose to Golden Meadow	03a.HP.20	$711M		$711M	
Morgan City Back Levee	03b.HP.10	$285M		$285M	
Morganza to the Gulf	03a.HP.02b	$16,564M		$16,564M	
Slidell Ring Levees	001.HP.13		$337M	$363M	
Upper Barataria Risk Reduction	002.HP.06		$1,624M	$1,882M	
West Shore Lake Pontchartrain	001.HP.05	$1,461M		$1,461M	
Grand Total		$28,393M	$9,674M	$31,497M	$5,927M

Figure 39: Selected Structural Risk Reduction Projects for the Maximize Risk Reduction Alternative.

In some cases, as anticipated, structural risk reduction projects were selected that could induce flooding in areas that did not have a nonstructural project selected (not shown). CPRA developed additional constraints that were added to the Modified Maximize Risk Reduction alternative to address this issue by specifically requiring some nonstructural projects to be selected if the structural project causing the induced flooding was selected (see section 3.4.3 for details).

Figure 40 shows the effect on coast wide risk (i.e., EAD) of the $25B, High environmental scenario, Maximize Risk Reduction alternative, which includes 12 structural and 32 NS projects. The risk reduction is significant—reducing year 25 EAD from over $7 billion to under $3 billion and reducing year 50 risk from about $20 billion to about $8 billion.

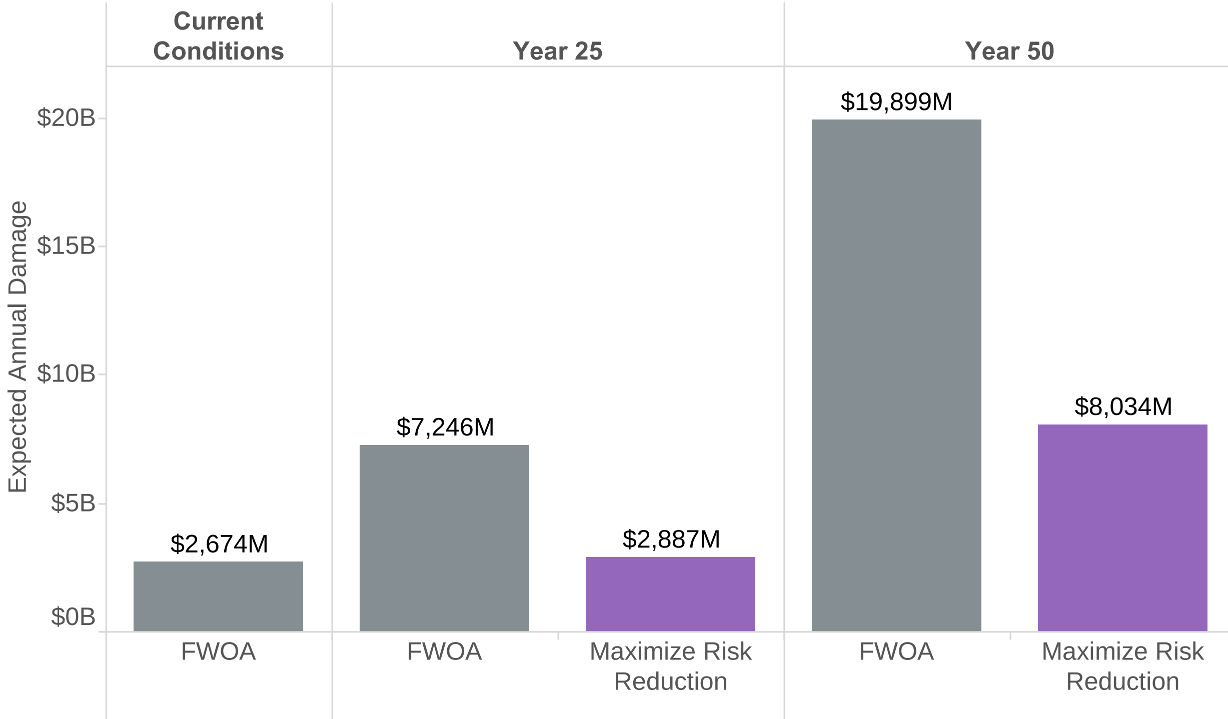


Figure 40: Expected Annual Damage Results in Years 25 and 50 (High Environmental Scenario) for the Future Without Action Condition and Maximize EAD Reduction Alternative.

3.4.2.3 Maximize Land Alternative Results

The Planning Tool selects a variety of different types of projects for the Maximize Land alternatives. Figure 41 shows the mixture of projects, in terms of expenditures, for the $25B, High environmental scenario, Maximize Land alternative. The two project types with the largest expenditures are Marsh Creation and Sediment Diversion projects, together accounting for $22.5 billion of the $25 billion funding amount. The remaining budget is allocated primarily to Barrier Island Restoration projects.

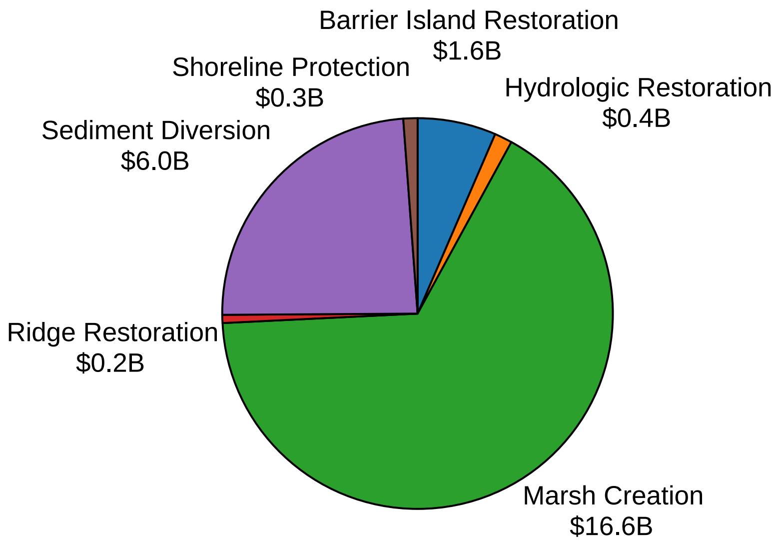


Figure 41: Cost Distribution for the Mixture of Projects Selected for the $25 billion, High Environmental Scenario Maximize Land Alternative.

Figure 42 shows the spatial distribution of restoration projects for the $25 billion, High environmental scenario, Maximize Land alternative. In this alternative, projects are selected across the coast; however, expenditures are concentrated in the East, where all but one sediment diversion project is located.

Figure 42: Distribution of Restoration Projects Included in the $25 Billion, High Maximize Land Alternative.

Unlike the risk reduction alternatives, the selected projects differ considerably across the environmental scenarios. Figure 43 shows that under all three environmental scenarios, between 6 and 11 sediment diversion projects are selected. The specific project location and version of the project selected does differ across the environmental scenarios. These differences exist for the other project types as well (not shown). The version 3 modeling of the three diversion projects (described above) leads to fewer differences across the scenarios, as these projects are more equally beneficial across the Medium and High environmental scenarios.

Project	Maximize Land; Low ES; $25B	Maximize Land; Medium ES; $25B	Maximize Land; High ES; $25B
03a.DI.01-0: Bayou Lafourche Diversion	◆		●
03a.DI.05-0: Atchafalaya River Diversion	◆	◆	●
03b.DI.04-0: Increase Atchafalaya Flow to Terrebonne	●		
001.DI.02-0: Lower Breton Diversion		●	●
001.DI.17-0: Upper Breton Diversion			◆
001.DI.18-0: Central Wetlands Diversion	◆	◆	●
001.DI.21-0: East Maurepas Diversion	●		
001.DI.23-0: Mid-Breton Sound Diversion		◆	●
001.DI.29-0: West Maurepas Diversion	◆		▼
001.DI.100-0: Manchac Landbridge Diversion			●
001.DI.101-0: Ama Sediment Diversion	◆		▼
001.DI.102-0: Union Freshwater Diversion			●
002.DI.03-0: Mid-Barataria Diversion		◆	
002.DI.03a-0: Mid-Barataria Diversion	◆	◆	
002.DI.15-0: Lower Barataria Diversion	◆		
002.DI.101-0: Mid-Barataria Diversion	●		▼

Implementation Period

● Years 1-10 ◆ Years 11-30 ▼ Years 31-50

Figure 43: Selected Sediment Diversion Projects for the $25 Billion Maximize Land Alternatives.

Figure 44 shows changes in land relative to FWOA over time for the $22.4 billion, $25 billion, and $30 billion alternatives formulated under the Medium environmental scenario (left graphs) and under the High environmental scenario (right graphs). The top row of graphs show the results under the Medium scenario and the bottom row of graphs show the results under the High scenario. This figure shows that the higher budgets generally lead to larger increases in land.

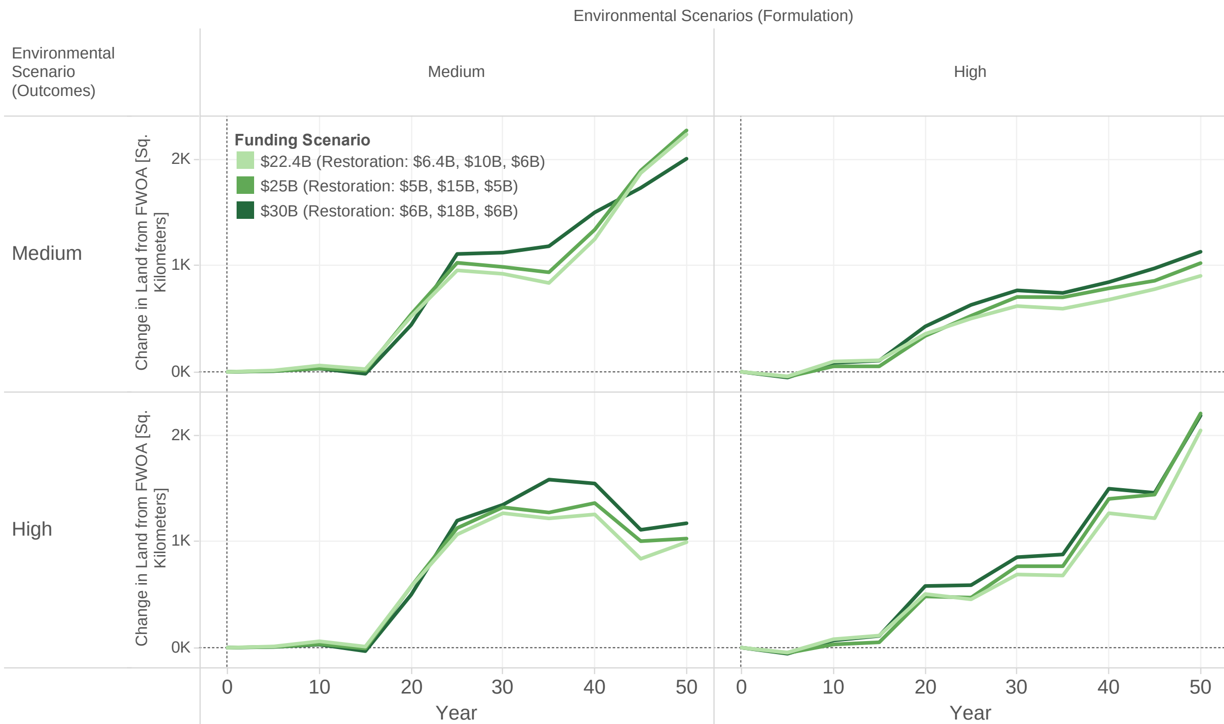


Figure 44: Change in Coast Wide Land Over Time Relative to Future Without Action Under Two Environmental Scenarios (rows) for the Future Without Action Condition and Maximize Land Alternative Formulated Under Three Funding Scenarios (colored lines) and Two Environmental Scenarios (columns).

Figure 45 shows, for the $25 billion alternatives, how land over time differs for the alternatives formulated for the three different environmental scenarios. Under the High scenario (right graph), the alternative formulated for the High scenario performs the best (red line) and the alternative formulated for the Medium and Low environmental scenarios perform less well. Similarly, and as expected, under the Medium environmental scenario, the alternative formulated for the Medium environmental scenario performs best.

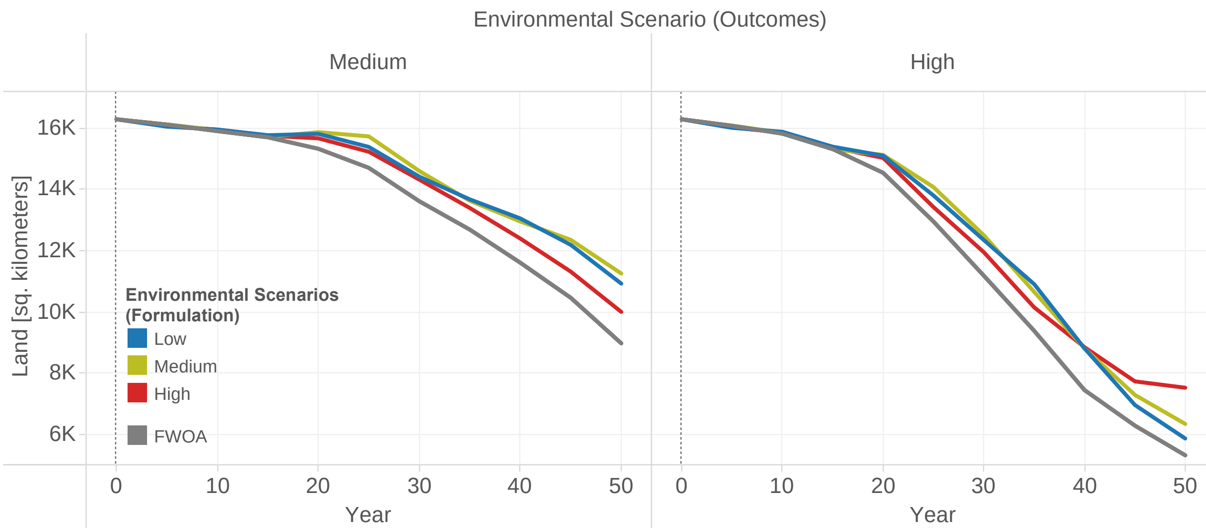


Figure 45: Coast Wide Land Over Time Under Two Environmental Scenarios (columns) for the Future Without Action Condition and Maximize Land Alternative Formulated Under Three Environmental Scenarios and the $25 Billion Funding Level.

This differences between land building and scenario used for formulation can be summarized by using a regret measure, where regret is defined as the difference in the average land for year 20 and 50 between a specific alternative and the alternative that performs best under that scenario. Figure 46 shows that the highest regret outcome would occur when formulating for the Low environmental scenario, yet facing the High environmental scenario. In this case, 804 million square meters of land would be foregone. Formulating for the High environmental scenario yet facing the Medium or Low scenarios could also lead to relatively high regret. It is likely that CPRA could reduce some of the negative effects that projects selected for the High environmental scenario could have in less severe environmental scenarios through different operations and the selection of different projects in later implementation periods. The modeling improvements between versions 1 and 3 also reduce the regret. This updating process is consistent with the 5-year interval for updating the master plan.

Environmental Scenario (Outcomes)	Environmental Scenarios (Formulation): Low	Medium	High
Low	0 sq. km	127 sq. km	673 sq. km
Medium	193 sq. km	0 sq. km	729 sq. km
High	804 sq. km	543 sq. km	0 sq. km

Figure 46: Matrix of Land Regret for the $25 Billion Maximize Land Alternatives.

3.4.3 Modified Maximize Risk Reduction and Maximize Land

Based on the results from the Maximize Risk Reduction and Maximize Land alternatives, CPRA proposed adjustments to the specifications to develop alternatives that were more consistent with ongoing CPRA activities, as well as an additional restoration alternative that include the version 3 modeling data, as described above.

For the Modified Maximize Risk Reduction alternative, CPRA specified the implementation period for key structural projects and specified that nonstructural projects selected in period 3 would be switched to variant 7, which is based on estimated year 25 flooding conditions. Also a few project prerequisite constraints were added to ensure that areas that would realize increased flooding due to a selected structural project would automatically receive a nonstructural project (see Table 11).

For the Modified Maximize Land alternative, CPRA made more specific adjustments. First, recognizing the restoration of Barrier Islands would be influenced by the effects of storms and that the modeling approach used in the ICM could not realistically predict the location of future storms, specific barrier island projects were removed from the alternative analysis and will instead be considered programmatically through CPRA's Breach Management Program. Second, sediment diversion projects selected in the third implementation period were specified to be selected in the first or second periods, recognizing that the offset of benefits used by the PT to reflect effects in later periods does not reflect the dynamics of land creation by sediment diversion projects. Lastly, a few projects were specifically switched to better reflect ongoing project planning and engineering and design activities at CPRA. For example, the Atchafalaya River Diversion project (03a.DI.05) was replaced the Increase Atchafalaya Flow to Terrebonne project (03b.DI.04), and the West Maurepas Diversion project (001.DI.29) was replaced with the East Maurepas Diversion project (001.DI.21).

Another Modified Maximize Land alternative was also developed that included new modeling results for five diversion projects most affected by the model improvements—denoted with suffix v3—, as described in Section 3.4.

3.4.3.1 Key Questions, Analysis, and Deliberation

- How would risk and land outcomes change under modifications to the Maximize Risk Reduction and Maximize Land alternatives?
- How would the specified changes affect the selection of other projects in the alternative?
- How does improved modeling of the FWOA condition and select projects change project selection and outcomes?

Table 10 provides a summary of the Modified Maximize Risk Reduction and Modified Maximize Land alternatives, and Table 11 lists all the nonstructural project prerequisites for select structural projects.

Table 10: Specifications for Modified Maximize Risk Reduction and Maximize Land Alternatives.

Alternative Sets	Objective Function	Funding Scenario	Environmental Scenarios	Other Constraints
Modified Maximize Risk Reduction	Maximize EAD Reduction	$25B	Medium and High	• Specification of structural project implementation periods • Nonstructural project prerequisites for select structural projects (Table 11) • Switching of nonstructural variation from 4 to 7 for those implemented in IP 3
Modified Maximize Land	Maximize Land Area	$25B	Medium and High	• Removing Barrier islands for all alternatives • Move Diversions selected for third period to second or first period. • Move Calcasieu Ship Channel Salinity Control Measures (004.HR.06) from second period to first period • Replace West Maurepas Diversion (001.DI.29) with East Maurepas Diversion (001.DI.21) • Replace Atchafalaya River Diversion project (03a.DI.05) with the Increase Atchafalaya Flow to Terrebonne project (03b.DI.04)

Alternative Sets	Objective Function	Funding Scenario	Environmental Scenarios	Other Constraints
Modified Maximize Land-v3	Maximize Land Area	$25B	High	• Removing Barrier islands for all alternatives • Move Diversions selected for third period to second or first period. • Move Calcasieu Ship Channel Salinity Control Measures (004.HR.06) from second period to first period • Use model version 3 results for East Maurepas Diversion, Increase Atchafalaya Flow to Terrebonne, and Union Freshwater Diversion • Include new versions of Mid-Barataria Diversion (002.DI.102) and Mid-Breton Sound Diversion (001.DI.104)

Table 11: Required Nonstructural Projects for Specific Structural Risk Reduction Projects.

Structural Projection Project	Required Nonstructural Projects
002.HP.06: Upper Barataria Risk Reduction	Lafourche – Raceland (LAF.03N) St. Charles – Salvador (STC.05N) Jefferson - Lafitte/Barataria (JEF.02N) Lafourche - Larose/Golden Meadow (LAF.02N)
001.HP.08: Lake Pontchartrain Barrier	Orleans – Rigolets (ORL.01N) St. Bernard (STB.02N)
03a.HP.102: Morganza to the Gulf - LGM enhanced inducements	Terrebonne – Lower (TER.01N) Lafourche – Lower (LAF.01N) Lafourche - Larose/Golden Meadow (LAF.02N)
03a.HP.02b: Morganza to the Gulf	Terrebonne – Lower (TER.01N) Lafourche – Lower (LAF.01N) Lafourche - Larose/Golden Meadow (LAF.02N)

Structural Projection Project	Required Nonstructural Projects
03a.HP.103: Morganza to the Gulf - LGM basic inducements	Terrebonne – Lower (TER.01N) Lafourche – Lower (LAF.01N) Lafourche - Larose/Golden Meadow (LAF.02N)
03a.HP.20: Larose to Golden Meadow	Lafourche – Lower (LAF.01N) Jefferson - Grand Isle (JEF.01N)
03a.HP.101: Larose to Golden Meadow (alt version)	Lafourche – Lower (LAF.01N) Jefferson - Grand Isle (JEF.01N)
03b.HP.14: Iberia/St. Mary Upland Levee	Vermilion (VER.01N)

These results were shared with the Framework Development Team during the June 2016 meeting. As described in Section 3.4.4, they suggested that CPRA consider additional alternatives that maintain shrimp habitat outcomes while still building land, reduce loss of freshwater wetlands, and increase the support of navigation.

3.4.3.2 Modified Maximize Risk Reduction Alternative Results

The Modified Maximize Risk Reduction alternative results show only modest differences in structural risk reduction project selection as compared to the Maximize Risk Reduction alternative. Specifically, adjustments to the implementation timing of structural projects shifted the large Greater New Orleans High Level project to the third implementation period and several smaller projects from the second to the first implementation period (Figure 47). The Modified Maximized Risk Reduction alternative also includes a different version of the Morganza to the Gulf project, per the specifications. Figure 48 summarizes the number of selected structural risk reduction and nonstructural risk reduction projects and their total expenditures for the Maximize Risk Reduction and Modified Maximize Risk Reduction alternatives ($25B, High Environmental Scenario).

Name	Code	**Maximize Risk Reduction** High ES Risk $25B Periods 1/2	**Maximize Risk Reduction** High ES Risk $25B Period 3	**Modified Maximize Risk Reduction** High ES Risk $25B Periods 1/2	**Modified Maximize Risk Reduction** High ES Risk $25B Period 3
Abbeville and Vicinity	004.HP.15		$755M		$755M
Amelia Levee Improvements	03b.HP.08		$866M	$1,052M	
Franklin and Vicinity	03b.HP.12	$430M			$381M
Greater New Orleans High Level	001.HP.04	$2,277M			$2,223M
Iberia/St Mary Upland Levee	03b.HP.14		$1,342M	$1,482M	
Lake Pontchartrain Barrier	001.HP.08	$2,410M		$2,410M	
Larose to Golden Meadow	03a.HP.20	$355M		$355M	
Morgan City Back Levee	03b.HP.10	$142M			$140M
Morganza to the Gulf	03a.HP.02b	$8,282M			
Morganza to the Gulf - LGM basic inducements	03a.HP.103			$8,832M	
Slidell Ring Levees	001.HP.13	$181M		$181M	
Upper Barataria Risk Reduction	002.HP.06	$941M		$941M	
West Shore Lake Pontchartrain	001.HP.05	$730M		$730M	
Grand Total		$15,749M	$2,964M	$15,983M	$3,499M

Figure 47: Selected Structural Risk Reduction Projects and Costs for the $25B, High Environmental Scenario Maximize Risk Reduction and Modified Maximize Risk Reduction Alternatives.

		Structural Risk Reduction	Nonstructural Risk Reduction	Grand Total
Maximize Risk Reduction	Periods 1/2	9 $15,749M	28 $4,686M	37 $20,435M
	Period 3	3 $2,964M	4 $1,596M	7 $4,560M
Modified Max Risk Reduction	Periods 1/2	8 $15,983M	25 $4,139M	33 $20,122M
	Period 3	4 $3,499M	3 $1,815M	7 $5,315M

Figure 48: Summary of Structural and Nonstructural Risk Reduction Project Expenditures For the Maximize Risk Reduction and Modified Maximize Risk Reduction Alternatives ($25B, High Environmental Scenario).

The Modified Maximize Risk Reduction alternative also modifies the nonstructural projects selected in implementation period 3 from variant 4 to variant 7, which uses year 25 rather than 10 for its elevation standard. Figure 49 shows the locations and implementation time for all risk reduction projects for the $25 billion, High environmental scenario Modified Maximize Risk Reduction alternative. The selection of nonstructural projects is based on the cost effectiveness of individual projects. Specifically, the non-selected nonstructural projects have low cost effectiveness relative to the other selected projects. As shown above, a larger budget that would include these additional projects would not reduce risk significantly due to the low effectiveness of these excluded nonstructural projects.

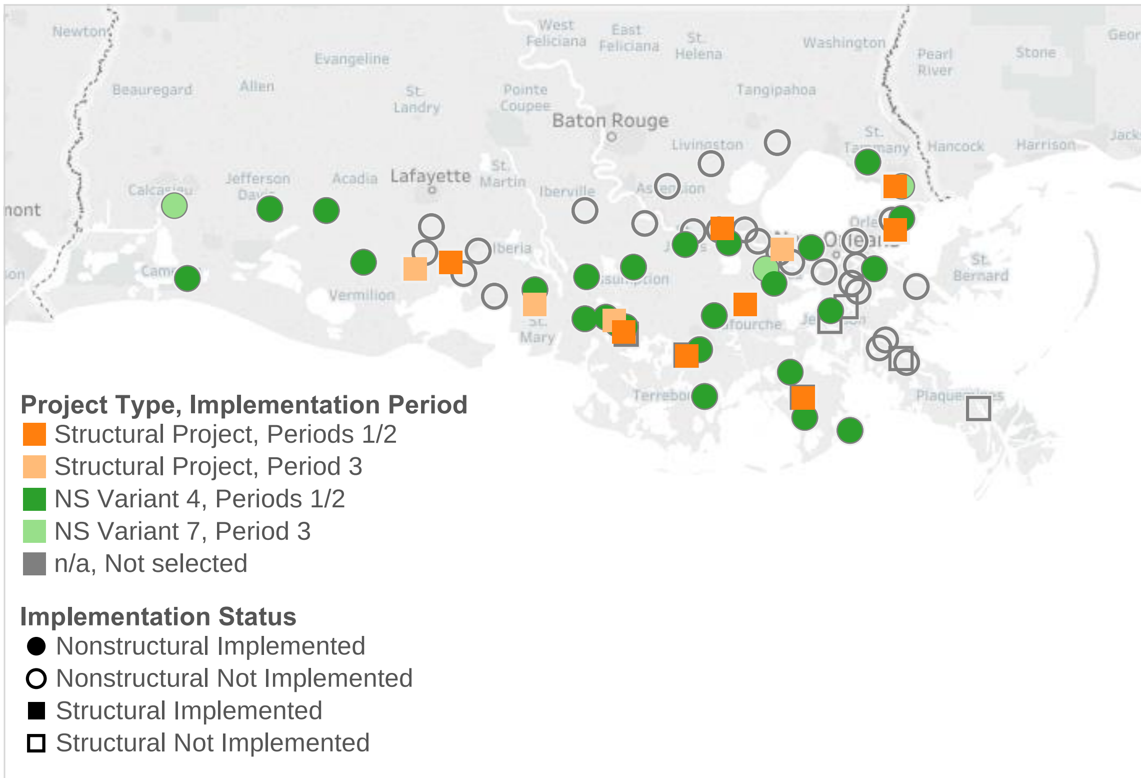


Figure 49: Locations of Selected Risk Reduction Projects by Implementation Period and Project Type for the Modified Risk Reduction Alternative, $25B, High Environmental Scenario.

The Modified Maximize Risk Reduction alternative leads to slightly higher risks in year 50 due to the added constraints on selected projects as well as the ICM and CLARA model updates described in Section 3.4 (Figure 50). However, the modified alternative still leads to significant risk reduction in years 25 and 50.

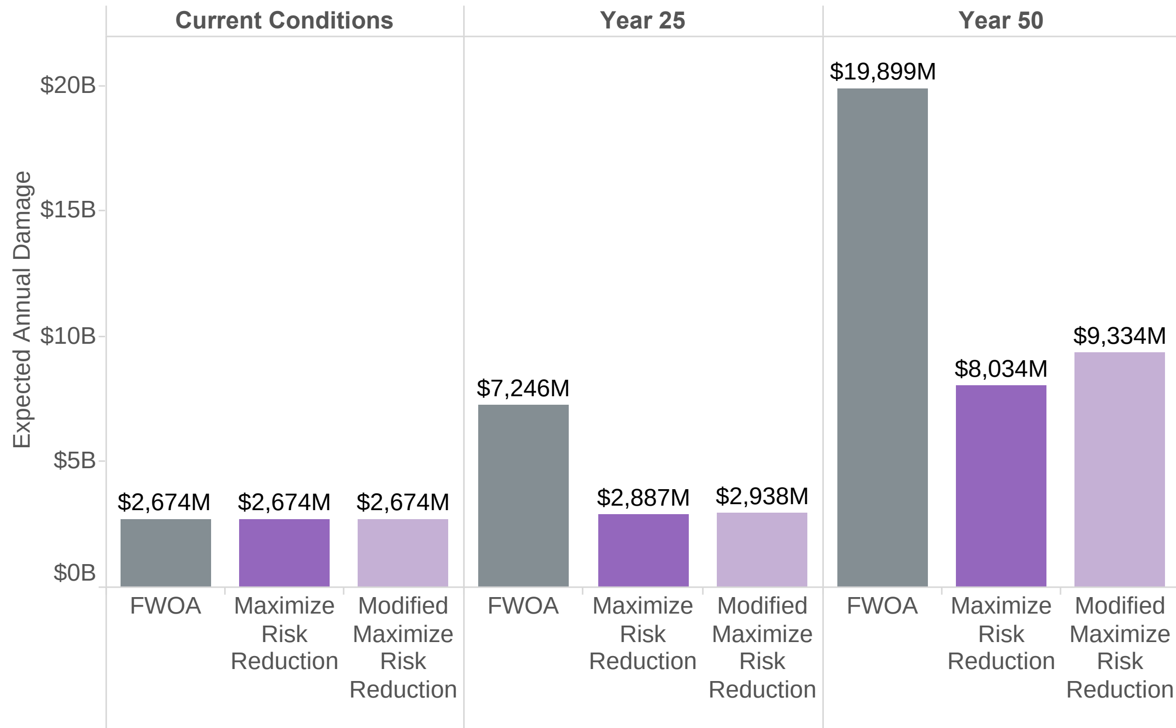


Figure 50: Expected Annual Damage Results in Years 25 and 50 (High Environmental Scenario) for the Future Without Action Condition, the Maximize EAD Reduction Alternative, and the Modified Maximize EAD Reduction Alternative.

3.4.3.3 Modified Maximize Land Alternative Results

There are large differences between the selected projects for the Modified Maximize Land alternatives and the Maximize Land alternatives. Removal of all the Barrier Island Restoration projects leads to increased allocation of funds to Marsh Creation projects in the $25 billion, High environmental scenario Modified Maximize Land alternative (Figure 51). The specification that the Mid-Barataria Diversion be selected in the first period also uses funding that previously had been allocated to the Union Freshwater Diversion project. Since the Union Freshwater Diversion project performs less well, when implemented in the second period, it is not selected in the Modified Maximize Land alternative (Figure 52). For the Modified Maximize Land-v3 alternative, the Planning Tool selects the version 3 of the East Maurepas Diversion, Increase Atchafalaya Flow to Terrebonne, and Union Freshwater Diversion projects, rather than having them specified to be selected, as was done in the Modified Maximize Land alternative.

	Maximize Land; High ES; $25B	Modified Maximize Land; High ES; $25B	Modified Maximize Land-v3; High ES; $25B
Barrier Island Restoration	$1,622M		
Hydrologic Restoration	$369M	$371M	$371M
Marsh Creation	$16,563M	$18,796M	$19,020M
Ridge Restoration	$170M	$162M	$155M
Sediment Diversion	$5,981M	$5,380M	$5,061M
Shoreline Protection	$290M	$289M	$387M
Grand Total	$24,994M	$24,998M	$24,995M

Figure 51: Summary of Selected Project Expenditures by Type for Maximize Land and Modified Maximize Land Alternatives ($25B funding, High Environmental Scenario).

Note: Shading is scaled to the expenditures by project type.

Project	Maximize Land; High ES; $25B	Modified Maximize Land; High ES; $25B	Modified Maximize Land-v3; High ES; $25B
03a.DI.01-0: Bayou Lafourche Diversion	●	●	●
03a.DI.05-0: Atchafalaya River Diversion	●		●
03b.DI.04-0: Increase Atchafalaya Flow to Terrebonne		◆	
03b.DI.04-0: Increase Atchafalaya Flow to Terrebonne V3			●
001.DI.02-0: Lower Breton Diversion	●	●	●
001.DI.17-0: Upper Breton Diversion	◆	◆	
001.DI.18-0: Central Wetlands Diversion	●	●	●
001.DI.21-0: East Maurepas Diversion		◆	
001.DI.21-0: East Maurepas Diversion V3			●
001.DI.23-0: Mid-Breton Sound Diversion	●	●	●
001.DI.29-0: West Maurepas Diversion	▼		
001.DI.100-0: Manchac Landbridge Diversion	●	●	●
001.DI.101-0: Ama Sediment Diversion	▼	◆	◆
001.DI.102-0: Union Freshwater Diversion	●		
001.DI.102-0: Union Freshwater Diversion V3			●
002.DI.101-0: Mid-Barataria Diversion	▼	●	●

Implementation Period

● Years 1-10 ◆ Years 11-30 ▼ Years 31-50

Figure 52: Summary of Selected Diversion Projects for Maximize Land and Modified Maximize Land Alternatives ($25B Funding, High Environmental Scenario).

The differences in selected projects for the Modified Maximize Land alternative lead to a slight reduction in land by year 50 as compared to the Maximize Land alternative (Figure 53). The decline in land by year 50 is largely due to the removal of the Barrier Island projects, many of which had previously been selected in the third implementation period. The Modified Maximize

Land-v3 alternative, however, shows improved performance due to the model version 3 projects, which compensates for the other factors leading to less amount of land by year 50.[15]

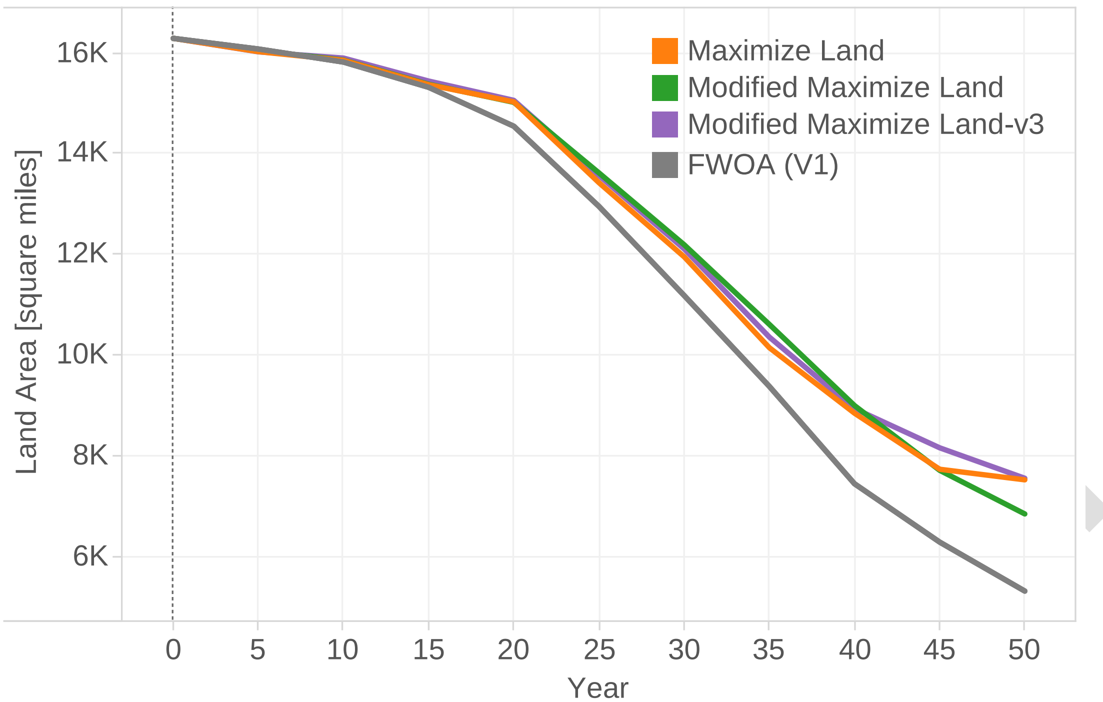


Figure 53: Land Over Time Under the High Environmental Scenario for Future Without Action, Maximize Land and Modified Maximize Land Alternatives ($25B funding, High Environmental Scenario).

3.4.4 Stakeholder Suggested Sensitivities

In response to suggestions from the FDT stakeholders, the Planning Tool was used to explore the feasibility of improving ecosystem outcomes with respect to Juvenile Small Brown Shrimp habitat and Juvenile Small White Shrimp habitat. The Planning Tool also evaluated the value of including more restoration projects beneficial to navigation.[16]

3.4.4.1 Key questions, analysis, and deliberations

- Can shrimp habitat be improved without substantial reductions in land outcomes?
- Which projects are excluded and included when shrimp constraints are added?
- Are projects beneficial to navigation being selected?

[15] Note that the project effects from the model version 3 projects are relative to model version 3 FWOA conditions.
[16] The FDT also requested that CPRA look at increasing Freshwater Wetlands. However, after recognizing that the Modified Maximize Land was already improving over the Future Without Action projection of Freshwater Wetlands, the analysis was not prioritized.

To evaluate the effects of improving Brown Shrimp and White Shrimp habitat on land, the Planning Tool was modified to include constraints that specified that Juvenile Small Brown and White Shrimp habitat could not decline below initial levels. The Planning Tool was also used to review restoration projects that were not included in the Maximize Land alternatives to see if any would be particularly beneficial to navigation. Table 12 summarizes the developed alternatives.

Table 12: Specifications for Sensitivity Analysis Alternatives.

Alternative Sets	Objective Function	Funding Scenario	Environmental Scenarios	Other Constraints
Maintain Brown Shrimp, Maximize Land	Maximize Land	$25B	High	Juvenile Small Brown Shrimp to remain greater than or equal to current levels at year 20 and year 50
Maintain White Shrimp, Maximize Land	Maximize Land	$25B	High	Juvenile Small White Shrimp to remain greater than or equal to current levels at year 50. [Maintaining at year 20 was not feasible.] Modified Maximize Land constraints

These results were discussed with the FDT stakeholder group in August 2016. CPRA reviewed the results and concluded that the information gained was useful to understand tradeoffs but did not strongly suggest that any modifications should be done to the Modified Maximize Land alternative based on these considerations.

3.4.4.2 Brown Shrimp Sensitivity Results

The Brown Shrimp sensitivity analysis was the most extensive of the sensitivity analyses. The motivation for considering improving Brown Shrimp habitat is seen in Figure 54, which shows a decline of more than 20 percent in Juvenile Small Brown Shrimp habitat by year 50 for the Maximize Land alternative. The brown line shows that Brown Shrimp habitat is stabilized under the Maintain Brown Shrimp, Maximize Land alternative. The grey line shows that under FWOA conditions, when most land is lost, brown shrimp habitat increases.

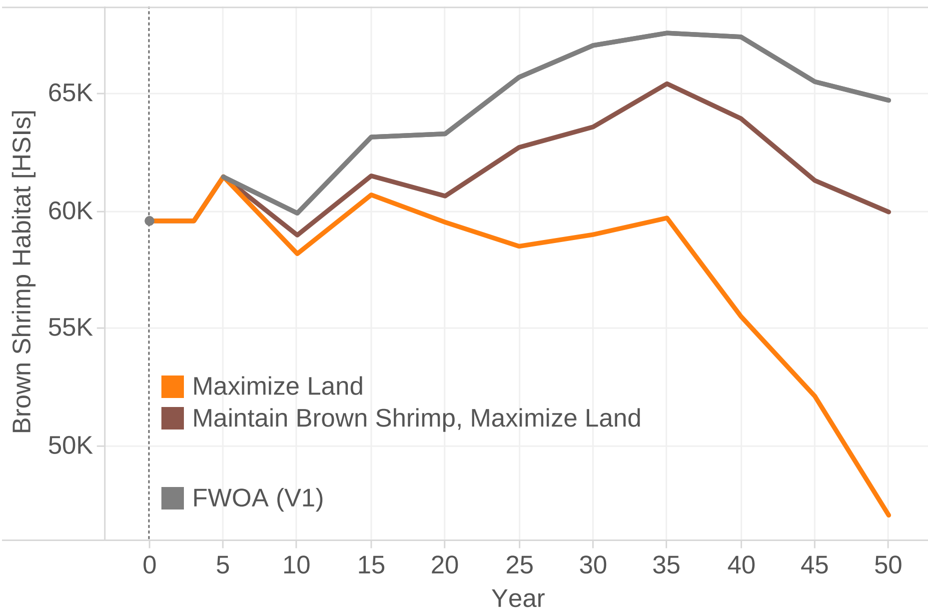


Figure 54: Brown Shrimp Habitat for Future Without Action (Gray Line), Maximize Land Alternative, $25B, High Environmental Scenario (Orange Line), and Maintain Brown Shrimp, Maximize Land (Brown Line).

There are significant project selection differences when the maintain-brown-shrimp constraint is added. Figure 55 summarizes of expenditures by project type for the two sets of alternatives. Significantly, the Maintain Brown Shrimp alternative does not fully expend the budget—leaving more than $4 billion unspent – showing that the other projects available for selection did not support maintenance of brown shrimp habitat. There are significant reductions in expenditures in both marsh creation and sediment diversion projects.

	Maximize Land; High ES; $25B	Maintain Brown Shrimp, Maximize Land; High ES; $25B
Bank Stabilization		$186M
Barrier Island Restoration	$1,622M	$2,863M
Hydrologic Restoration	$369M	$100M
Marsh Creation	$16,563M	$13,889M
Ridge Restoration	$170M	$155M
Sediment Diversion	$5,981M	$2,928M
Shoreline Protection	$290M	$573M
Grand Total	$24,994M	$20,693M

Figure 55: Summary of Selected Projects by Type for Maximize Land and Maintain Brown Shrimp, Maximize Land Alternatives ($25B funding, High Environmental Scenario).

Figure 56 shows the specific diversion and marsh creation projects that are selected for the Maximize Land and Maintain Brown Shrimp alternatives. The columns in the figure indicate which project increment is implemented for those marsh creation projects with increments. Projects marked in the “n/a” column are implemented projects that are not divided into increments. For the Maintain Brown Shrimp alternative, several diversion projects, including Upper and Mid-Breton Diversions, are not selected which would reduce the amount of fresh water in areas of high Brown Shrimp habitat. Some marsh creation projects are also not selected leaving regions with high Brown Shrimp habitat values as open water or fragmented marsh rather than filling them with dredged material.

	Project increment -->	Maximize Land; High ES; $25B n/a	1	2	3	4	Maintain Brown Shrimp, Max Land; High ES; $25B n/a	1	2	3	4
Sediment Diversion	03a.DI.01: Bayou Lafourche Diversion	●					●				
	03a.DI.05: Atchafalaya River Diversion	●					●				
	001.DI.02: Lower Breton Diversion	●					●				
	001.DI.17: Upper Breton Diversion	◆									
	001.DI.18: Central Wetlands Diversion	●					●				
	001.DI.23: Mid-Breton Sound Diversion	●									
	001.DI.29: West Maurepas Diversion	▼									
	001.DI.100: Manchac Landbridge Diversion	●					●				
	001.DI.101: Ama Sediment Diversion	▼									
	001.DI.102: Union Freshwater Diversion	●					●				
	002.DI.15: Lower Barataria Diversion						◆				
	002.DI.101: Mid-Barataria Diversion	▼									
Marsh Creation	03a.MC.07: Belle Pass-Golden Meadow Marsh Creation		◆	◆	◆	◆		◆	◆	◆	◆
	03a.MC.09b: North Terrebonne Bay Marsh Creation - Component B	◆					◆				
	03a.MC.100: South Terrebonne Marsh Creation		●	◆	◆	◆				◆	
	03a.MC.101: North Lake Mechant Marsh Creation		◆	◆	◆					◆	
	03b.MC.03: Marsh Island Marsh Creation		◆	◆	◆			◆	◆	◆	
	03b.MC.07: East Rainey Marsh Creation				●			●	●	●	
	03b.MC.09: Point Au Fer Island Marsh Creation		▼	▼	▼			●	●	●	
	03b.MC.100: Vermilion Bay Marsh Creation							●	●		
	03b.MC.101: Southeast Marsh Island Marsh Creation	●					●				
	001.MC.02: Hopedale Marsh Creation						◆				
	001.MC.05: New Orleans East Landbridge Restoration		●	●	●	●		◆	◆	◆	●
	001.MC.06a: Breton Marsh Creation - Component A		◆	◆	◆						
	001.MC.07a: Lake Borgne Marsh Creation - Component A	◆									
	001.MC.08a: Central Wetlands Marsh Creation - Component A	◆					◆				
	001.MC.09: Biloxi Marsh Creation							◆	◆	◆	◆
	001.MC.13: Golden Triangle Marsh Creation	▼					◆				
	001.MC.17: Eastern Lake Borgne Marsh Creation						◆				
	001.MC.100: Sunrise Point Marsh Creation	◆					◆				
	001.MC.101: Uhlan Bay Marsh Creation						▼				
	001.MC.102: Pointe a la Hache Marsh Creation		◆		◆			◆		●	
	001.MC.103: Fritchie North Marsh Creation	◆					◆				
	001.MC.104: East Bank Land Bridge Marsh Creation	◆					◆				
	001.MC.105: Spanish Lake Marsh Creation	◆					◆				
	001.MC.106: St. Tammany Marsh Creation	◆									
	001.MC.107: Tiger Ridge/Maple Knoll Marsh Creation	◆					◆				
	001.MC.108: Guste Island Marsh Creation	●					●				
	002.MC.05e: Large-Scale Barataria Marsh Creation - Component E		◆	◆	◆			◆	◆	◆	
	002.MC.07: Barataria Bay Rim Marsh Creation	◆					◆				
	002.MC.100: North Barataria Bay Marsh Creation									▼	
	004.MC.01: South Grand Chenier Marsh Creation	◆					●				
	004.MC.04: Mud Lake Marsh Creation	◆					◆				
	004.MC.07: West Rainey Marsh Creation		●	●				●	●		
	004.MC.10: Southeast Calcasieu Lake Marsh Creation	◆					◆				
	004.MC.13: Cameron Meadows Marsh Creation	◆					●				
	004.MC.16: East Pecan Island Marsh Creation		◆	◆	◆			◆	◆	◆	
	004.MC.19: East Calcasieu Lake Marsh Creation		▼	▼	▼						
	004.MC.23: Calcasieu Ship Channel Marsh Creation	◆					◆				
	004.MC.25: Kelso Bayou Marsh Creation						◆				
	004.MC.100: Freshwater Bayou North Marsh Creation		●	●	●			●	●	●	
	004.MC.101: Freshwater Bayou South Marsh Creation	●					●				
	004.MC.102: White Lake Marsh Creation		◆	◆							
	004.MC.103: Little Chenier Marsh Creation						◆				
	004.MC.104: Calcasieu Lake West Bank Marsh Creation		◆	▼				◆	◆		
	004.MC.105: West Brown Lake Marsh Creation		▼								
	004.MC.107: West Sabine Refuge Marsh Creation		◆	◆	◆			◆	◆	◆	

Implementation Period
● Years 1-10 ◆ Years 11-30 ▼ Years 31-50

Figure 56: Selected Diversion and Marsh Creation Projects (by Segment) for Maximize Land and Maintain Brown Shrimp, Maximize Land Alternatives ($25B funding, High Environmental Scenario).

The implications of these project changes on land are significant. Figure 57 shows that the amount of land building by year 50 is about halved when maintaining brown shrimp habitat.

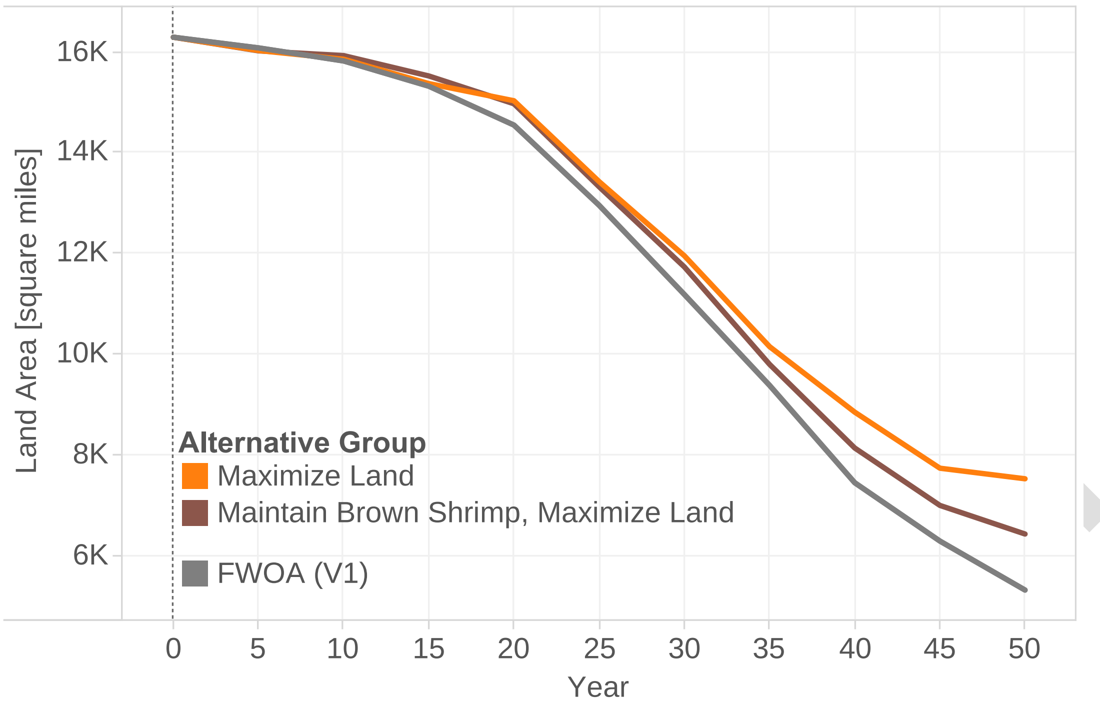


Figure 57: Land Over Time Under High Environmental Scenario for Future Without Action (Gray Line), Maximize Land (Orange Line), and Maintain Brown Shrimp, Maximize Land Alternatives ($25B funding, High Environmental Scenario).

However, an examination of the Brown Shrimp outcomes under the Modified Maximize Land alternative shows, perhaps, an acceptable tradeoff. While the Modified Maximize Land alternative does not completely maintain Juvenile Small Brown Shrimp over the 50-year time horizon, the year 20 and year 50 outcomes are only slightly lower than current levels (Figure 58). Recall that the land outcomes for the Modified Maximize Land alternative showed only a minor reduction from Maximize Land alternative (section 3.4.3). As a result of this analysis, CPRA decided not to make any additional adjustments to the Modified Maximize Land alternative on account of Brown Shrimp.

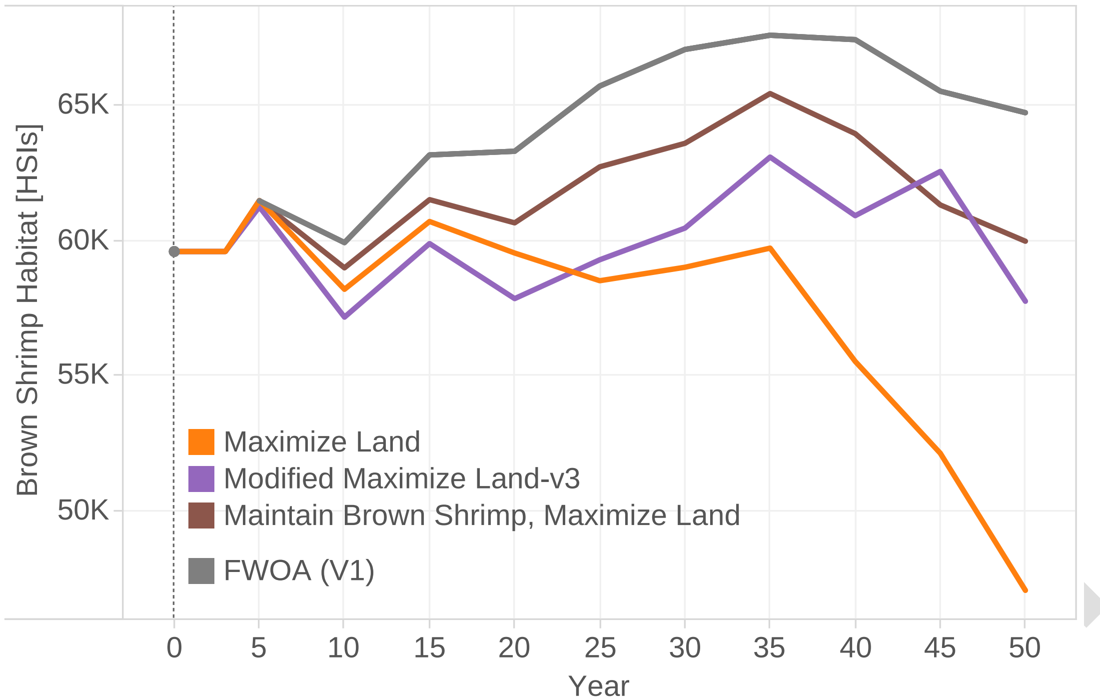


Figure 58: Juvenile Small Brown Shrimp Habitat for Future Without Action (Gray Line) and the Maximize Land Alternative (Orange Line), Maintain Brown Shrimp, Maximize Land (Brown Line), and Modified Maximize Land (Purple Line) Alternatives (for $25B, High Environmental Scenario).

3.4.4.3 White Shrimp Sensitivity Results

The White Shrimp sensitivity analysis led to similar conclusions. As with Brown Shrimp, Juvenile Small White Shrimp habitat also shows modest declines under the Maximize Land alternative (orange line of Figure 59) but increases under FWOA. When including the other Modified Maximize Land constraints, there is not a feasible solution that would lead to year 20 white shrimp being maintained. As with the Brown Shrimp case, however, the Modified Maximize Land alternative also leads to favorable shrimp outcomes. In this case, year 50 year White Shrimp Habitat is slightly greater than current levels. Therefore, CPRA also determined that no additional changes to the Modified Maximize Land alternative were warranted on account of White Shrimp.

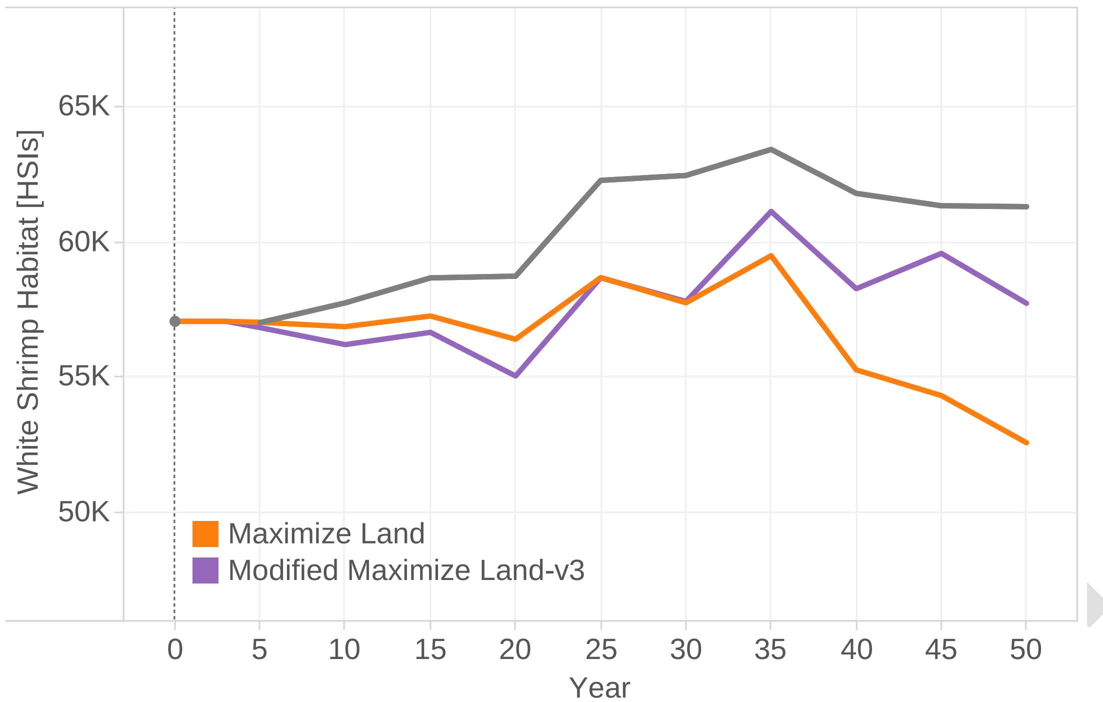


Figure 59: Juvenile Small White Shrimp Habitat for Future Without Action (Gray Line) and the Maximize Land Alternative (Orange Line) and Modified Maximize Land (Purple Line) Alternatives (for $25B, High Environmental Scenario).

3.4.4.4 Supporting Navigation Sensitivity Results

The Planning Tool was used to explore whether projects that would be beneficial to navigation were being included. Figure 60 shows that all but one Diversion or Marsh Creation project that has a navigation score of greater than or equal to 0.05 is already selected by the Modified Maximize Land, $25 Billion, High alternative. Figure 61 shows the same information as Figure 60, except for all other restoration project types. It shows that only a few shoreline protection projects and one oyster reef project with high navigation scores are not selected. These projects have very low or no land effects. Therefore, CPRA concluded that replacing projects that have positive land effects with any of these projects would not be consistent with CPRA objectives.

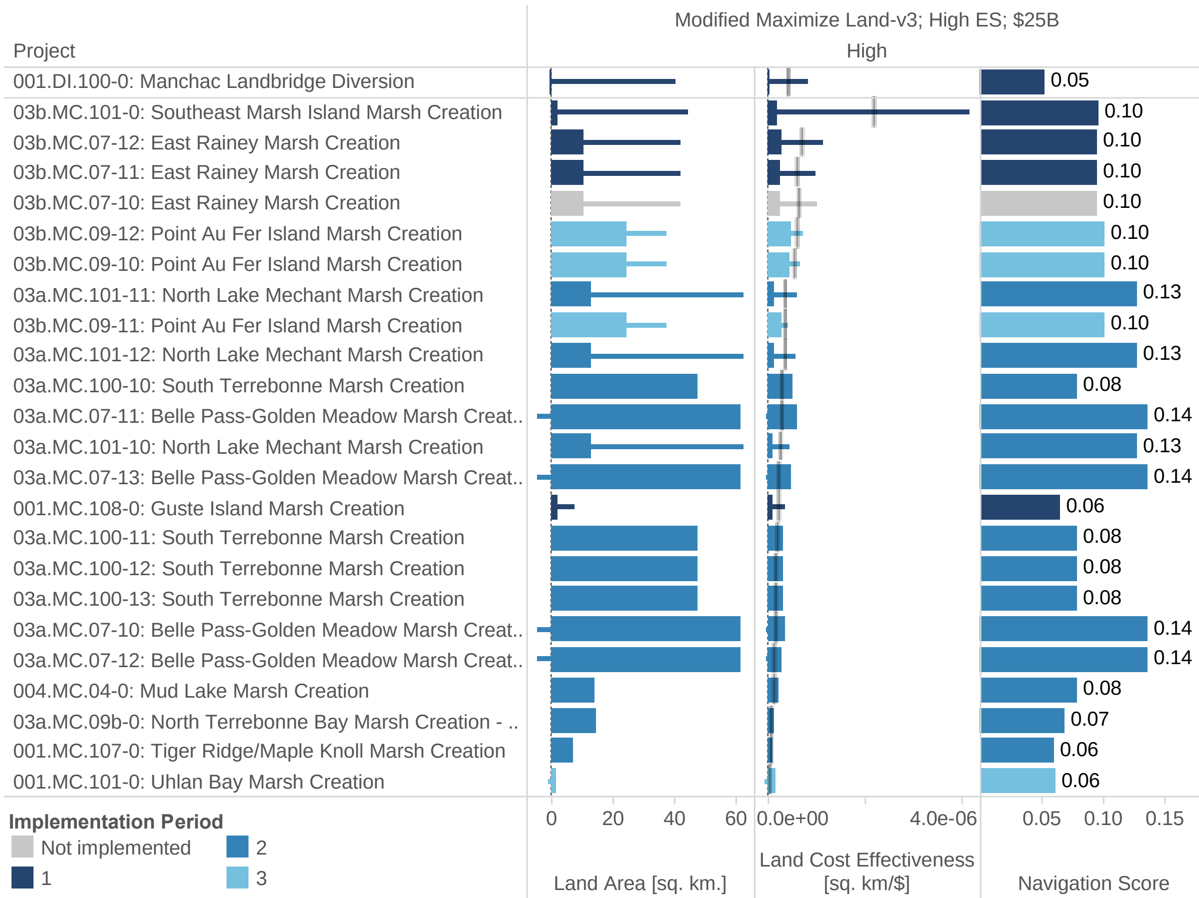


Figure 60: Sediment Diversion and Marsh Creation Projects With High Navigation Scores (>= 0.05) Ordered by Land Cost Effectiveness and Colored by Implementation in the Modified Maximize Land Alternative.

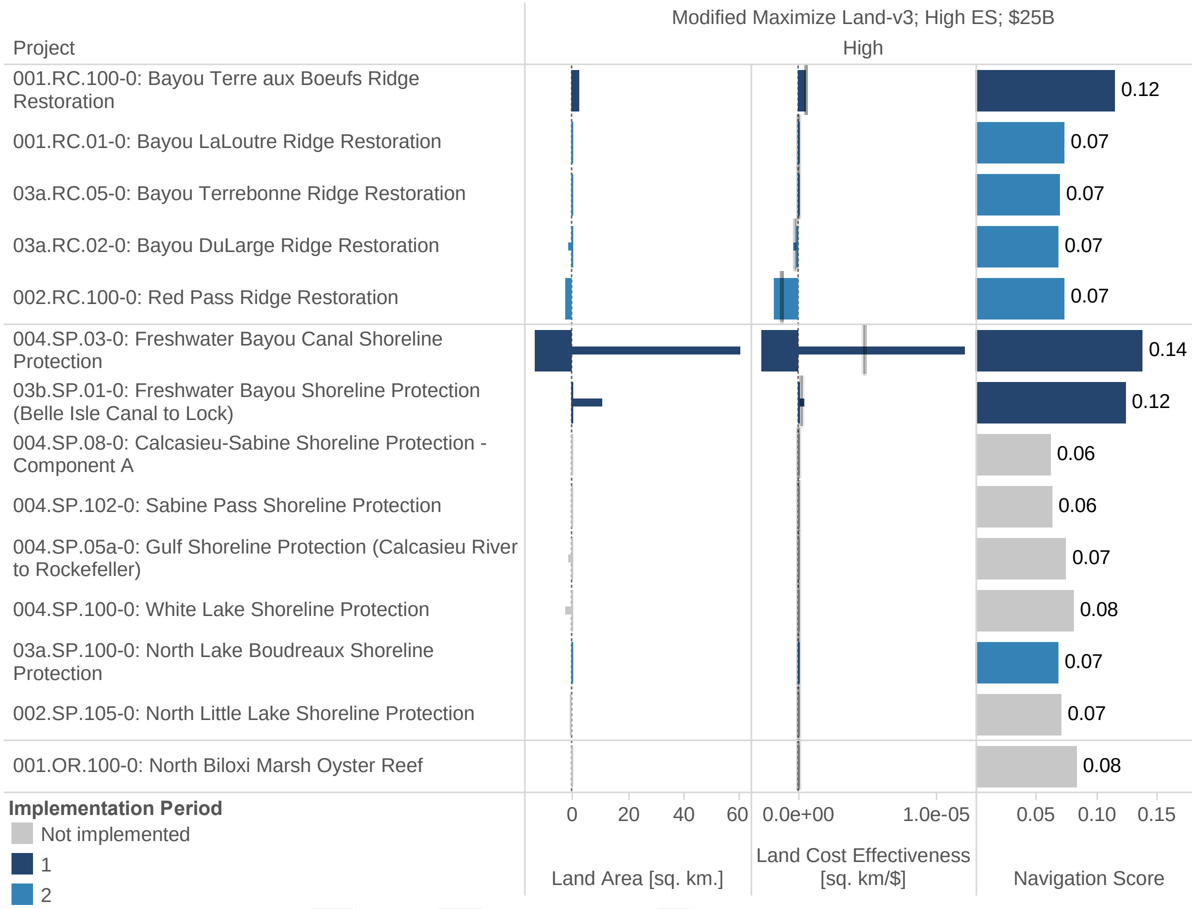


Figure 61: Other Restoration Projects With High Navigation Scores (>= 0.05) Ordered by Land Cost Effectiveness and Colored by Implementation in the Modified Maximize Land Alternative.

3.4.5 Systems Model Evaluation of Alternatives

The Planning Tool can only estimate the cumulative effects of an alternative on risk and restoration metrics using the assumption that individual project effects are additive. There is a wide range of conditions that could lead the additive assumption to either over- or under-estimate the aggregate benefits. For example, a Marsh Creation and Sediment Diversion project may build the same piece of land, leading the Planning tool to over-estimate their combined effect. However, two such projects could also reinforce land building in a particular region and thus the Planning Tool would under-estimate their benefit. The Planning Tool also has no information to evaluate how risk reduction projects might affect ecosystem metrics or how restoration projects might affect risk metrics.

During the alternative formulation process, the systems models evaluated several alternatives based on different alternatives formulated using the Planning Tool (Table 13).

Table 13: Select System Modeled Alternatives for Systems Model Evaluation.

System Modeled Alternatives	Risk Reduction Projects	Restoration Projects
Modified Maximize Risk Reduction Only (G303)	Risk reduction projects from Modified Maximize Risk Reduction alternative	none
Modified Maximize Land Only (G304)	none	Restoration projects from Modified Maximize Land alternatives
Modified Maximize Risk Reduction and Land (G301)	Risk reduction projects from Modified Maximize Risk Reduction alternative	Restoration projects from Modified Maximize Land alternatives

To model the complete alternatives, the ICM first estimates the evolution of the landscape and other ecosystem outcomes with the restoration and risk reduction projects added per the alternative specification. The storm surge/waves and risk assessment models then evaluate the risk reduction projects using the landscape over time calculated by the ICM (Figure 62).

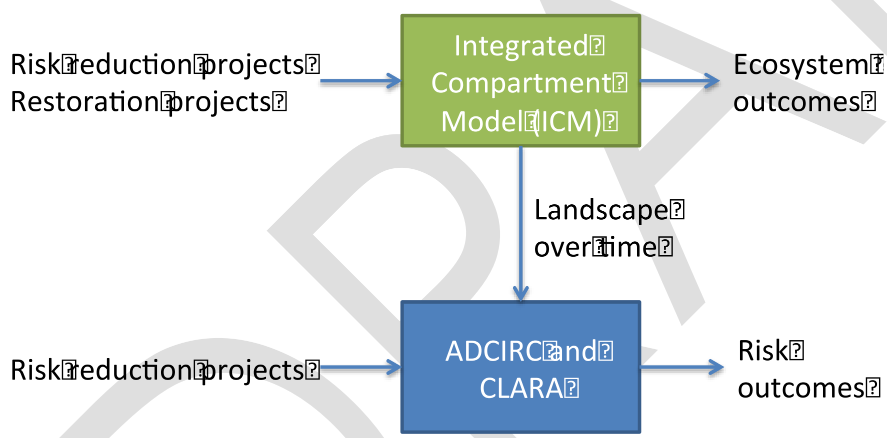


Figure 62: Overview of the Alternative Modeling Information Flows.

3.4.5.1 Risk Results for System Modeled Alternatives

Figure 63 shows coast wide EAD results for the FWOA condition and three alternatives. The first—Modified Maximize Risk Reduction—is based on Planning Tool results (as show in section 3.4.3.2). The second—Modified Maximize Risk Reduction Only (G303)—is the result for the alternative that includes only the risk reduction projects selected for the Modified Maximize Risk Reduction alternative. This alternative assumes that the landscape changes according to the FWOA estimate, modified by the risk reduction projects. In Year 50, CLARA estimates that coast wide risk under the High environmental scenario for the Modified Maximize Risk Reduction Only alternative would be $9,126M—only 2 percent more damage reduction then the Planning Tool estimate for the Modified Maximize Risk Reduction alternative. In this case, the Planning Tool's additive assumption does not distort the result for risk reduction from the risk reduction projects.

The third alternative—Modified Maximize Risk Reduction/Land Alternative (G301)—includes both the restoration and risk reduction projects' effects upon the landscape. The additional $948M of EAD reduction is due to additional land on the landscape when the Modified Maximize Land Alternative restoration projects are implemented. In other words, about 8 percent of the total risk reduction is due to land building.

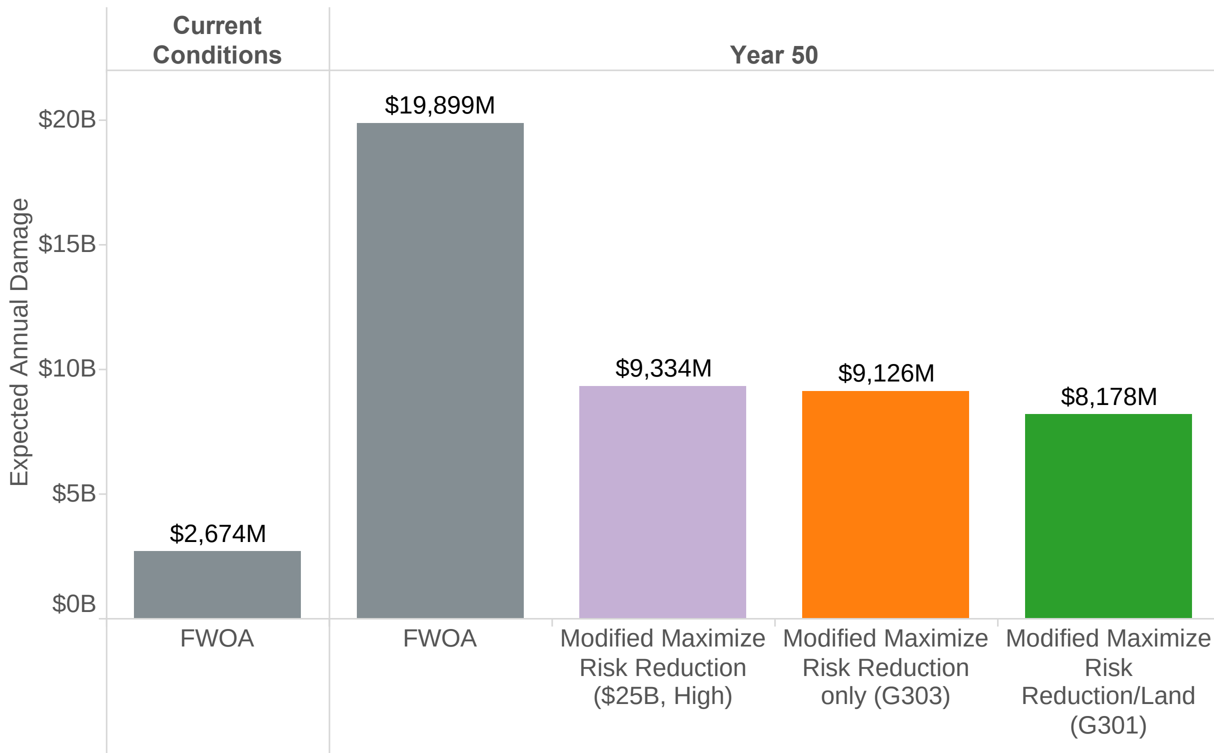


Figure 63: Expected Annual Damage in the Current Conditions and Year 50 for FWOA, the Planning Tool estimated Modified Maximize Risk Reduction Alternative, and Two Integrated Risk Alternatives for the High Environmental Scenario.

3.4.5.2 Restoration Results for System Modeled Alternatives

For the restoration alternatives, Figure 64 shows land over time for the Modified Maximize Land-v3 alternative based on the Planning Tool results (compared to model version 1 FWOA condition) and two of the system modeled alternatives based on ICM model results (and corresponding model version 3 FWOA condition). Due to the different FWOA condition for the Planning Tool alternative and the integrated alternatives, it is difficult to directly evaluate the Planning Tool's additive assumption. However, by year 50, land under the Modified Maximize Land Only alternative (which only includes restoration projects) is about the same amount higher (2,251 km^2) then the model version 3 FWOA as is land increase over model version 1 FWOA under the Modified Maximize Land-v3 (2,242 km^2). From this perspective, the coast wide land additivity assumption in the Planning Tool also seems not to distort the year 50 results.

The results for the Modified Maximize Risk Reduction/Land alternative, which includes the structural risk reduction projects, show slightly higher year 50 land than the Modified Maximize Land Only alternative. This suggests that some of the structural projects could have a positive effect on the landscape, likely by reducing salinity intrusion in later decades.

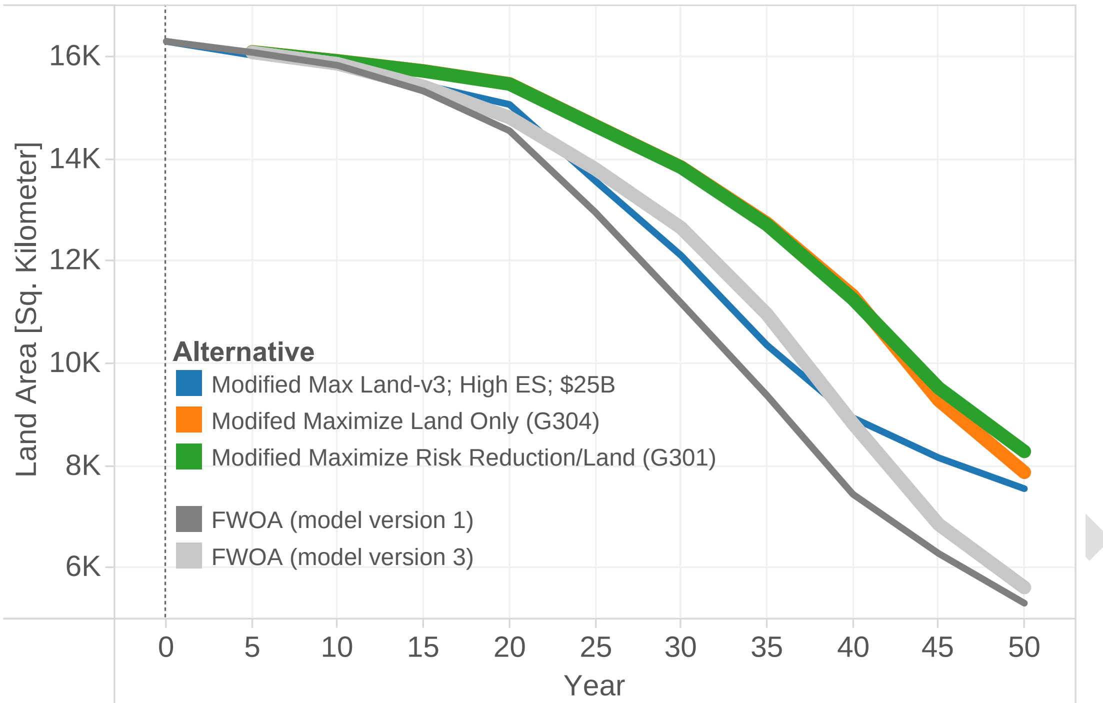


Figure 64: Land Area Over Time for the Modified Maximize Land-v3 Alternative and Two System Modeled Alternatives for the High Environmental Scenario.

3.5 Draft Master Plan

CPRA specified the Draft Master Plan alternative (risk reduction and restoration) based on the Planning Tool analysis presented in section 3.4, stakeholder discussions, and internal CPRA deliberations. The Draft Master Plan is a roughly $50B package, comprised of:

- $25B of risk reduction projects
- $23.5B of restoration projects
- $1.5B barrier island breach management program

Each of these components is described in detail below.

3.5.1 Draft Plan Risk Reduction

3.5.1.1 Formulation

The Risk Reduction component of the draft plan alternative was developed using the Modified Maximize Risk Reduction alternative as the basis for the structural projects, with one change to the version of the Morganza to the Gulf project—the draft plan Risk Reduction alternative specified version 03a.HP.02b. For the nonstructural projects, CPRA used the list based on the

Maximize Risk Reduction alternative and then made several modifications to better reflect CPRA priorities:

- include project areas that have high vulnerability (due to flood depths) but lower cost-effectiveness than recommended projects
- include project areas that are included in other ongoing studies (project areas that are recommended in the southwest coastal study)
- include project areas outside of proposed structural risk reduction
- exclude project areas on northern study area boundary that had low flood depths (even if more cost effective than projects not recommended)
- exclude project areas behind existing structural risk reduction

Due to time limitations to develop the set of projects for the draft plan, these manual changes were not programmed into the Planning Tool. These rules will be added to the Planning Tool if additional risk alternatives are required.

3.5.1.2 Included Risk Reduction Projects

Figure 65 shows the selected risk reduction projects and their costs for the draft plan alternative. Figure 66 summarizes the total expenditures for structural and nonstructural projects across the two implementation periods. Lastly, Figure 67 shows the locations of the risk reduction projects for the draft plan alternative.

	Name	Code	Draft Plan Risk Reduction	
			Periods 1/2	Period 3
Structural Risk Reduction	Abbeville and Vicinity	004.HP.15		$755M
	Amelia Levee Improvements	03b.HP.08	$914M	
	Franklin and Vicinity	03b.HP.12		$381M
	Greater New Orleans High Level	001.HP.04		$2,223M
	Iberia/St Mary Upland Levee	03b.HP.14	$1,482M	
	Lake Pontchartrain Barrier	001.HP.08	$2,410M	
	Larose to Golden Meadow	03a.HP.20	$355M	
	Morgan City Back Levee	03b.HP.10		$140M
	Morganza to the Gulf	03a.HP.02b	$8,282M	
	Slidell Ring Levees	001.HP.13	$181M	
	Upper Barataria Risk Reduction	002.HP.06	$941M	
	West Shore Lake Pontchartrain	001.HP.05	$730M	
Nonstructural Risk Reduction	Calcasieu	CAL.01N		$125M
	Cameron	CAM.01N	$127M	
	Iberia - Atchafalaya	IBE.02N	$289M	
	Iberia - Lower	IBE.01N	$1M	
	Jefferson - Grand Isle	JEF.01N	$98M	
	Jefferson - Lafitte/Barataria	JEF.02N	$201M	
	Lafourche - Larose/Golden Meadow	LAF.02N	$15M	
	Lafourche - Lower	LAF.01N	$2M	
	Lafourche - Raceland	LAF.03N	$363M	
	Orleans - Lake Catherine	ORL.02N	$136M	
	Orleans - Rigolets	ORL.01N	$18M	
	Plaquemines - Braithwaite	PLA.02N	$56M	
	Plaquemines - Grand Bayou	PLA.03N	$3M	
	Plaquemines - Phoenix/Pointe A La Hache	PLA.05N	$27M	
	Plaquemines - West Bank	PLA.01N	$262M	
	St. Bernard	STB.02N	$3M	
	St. Bernard - Yscloskey/Delacroix	STB.01N	$70M	
	St. Charles - Hahnville/Luling	STC.01N		$829M
	St. Charles - Salvador	STC.05N	$3M	
	St. James - Vacherie	STJ.02N		$4M
	St. John the Baptist - Edgard	SJB.03N	$8M	
	St. Martin	SMT.01N	$13M	
	St. Mary - Franklin/Charenton	STM.04N	$80M	
	St. Mary - Glencoe	STM.02N		$16M
	St. Mary - Lower	STM.05N	$7M	
	St. Mary - Morgan City	STM.01N		$2M
	St. Mary - Patterson	STM.03N		$3M
	St. Tammany	STT.01N	$1,611M	
	Terrebonne - Houma	TER.02N	$1,264M	
	Terrebonne - Lower	TER.01N	$88M	
	Vermilion	VER.01N	$110M	
	Vermilion - Abbeville/Delcambre	VER.02N	$191M	
			$20,344M	$4,479M

Figure 65: Risk Reduction Projects Included and Their Costs in the Draft Plan Alternative.

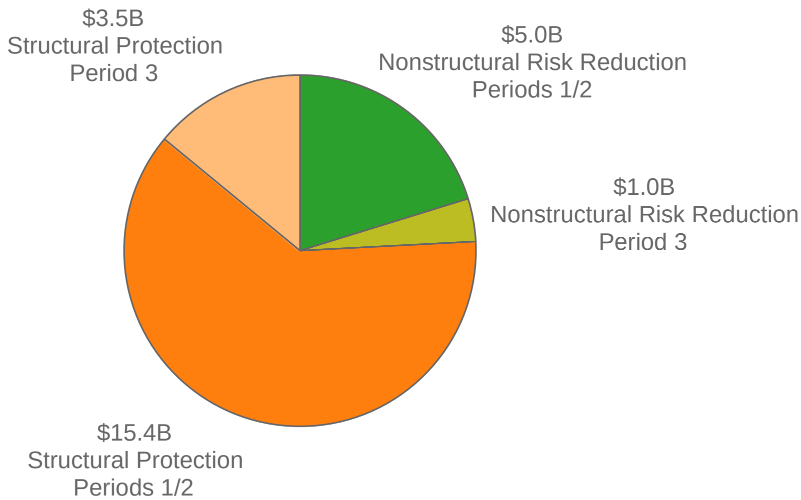


Figure 66: Summary of Risk Reduction Project Costs in the Draft Plan Alternative.

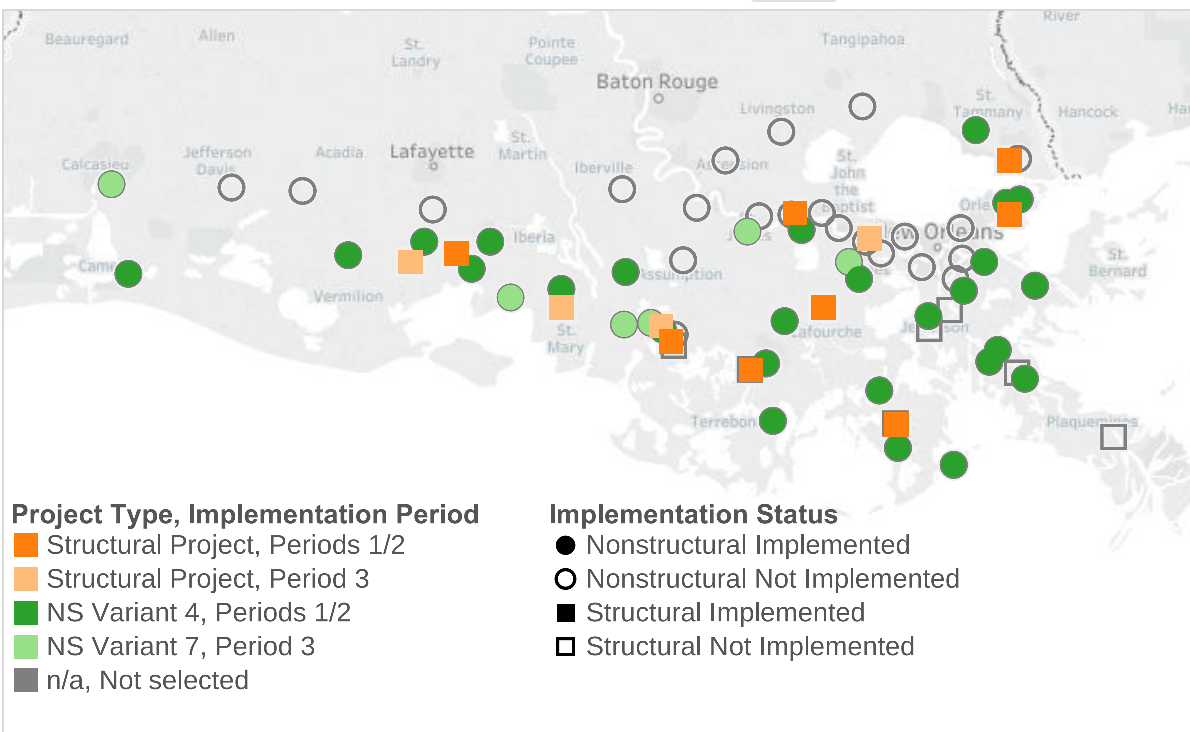


Figure 67: Locations of Risk Reduction Projects in the Draft Plan Alternative.

3.5.1.3 Risk Results

The storm surge/waves and risk assessment models were used to estimate the risk across the coast with the implementation of the draft master plan projects. Recall that for this calculation, the landscape used when evaluating storm surge reflects the ICM-estimated effects of the restoration and risk projects on land.

Figure 68 shows the coast wide risk for FWOA conditions and with the 2017 Draft Master Plan (G400) alternative for the Medium and High environmental scenarios. For the Medium environmental scenario, the 2017 Draft Master Plan limits the risk by year 50 to less than $4 billion, as compared to $12 billion in the FWOA. For the High environmental scenario, through year 25, the 2017 Draft Master Plan alternative keeps risk at current conditions levels (around $2.7 billion/year). From year 25 to year 50, risk increases significantly to about $7.7 billion/year, but reduces risk by more than $12 billion/year as compared to FWOA.

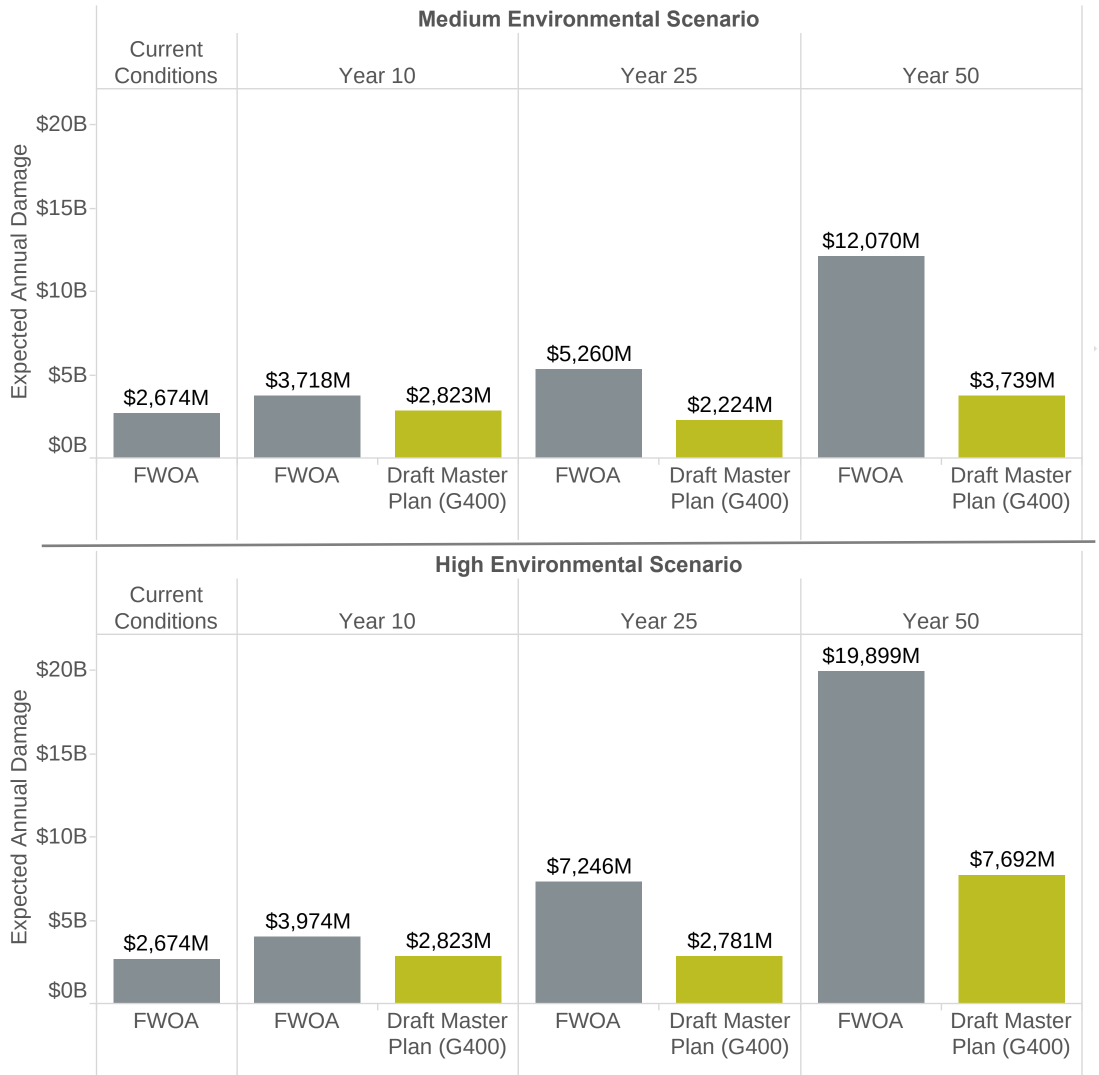


Figure 68: Expected Annual Damage in the Current Conditions and Years 10, 25, and 50 for FWOA and the Draft Master Plan (G400) for the Medium and High Environmental Scenarios.

Figure 69 shows the spatial pattern of risk under the Medium environmental scenario for the FWOA condition (top), with the 2017 Draft Master Plan in place (middle), and the change in risk due to the master plan (bottom). The draft master plan reduces risk the most in the Terrebonne – Houma risk area (from $2.9 billion to $0.7 billion).

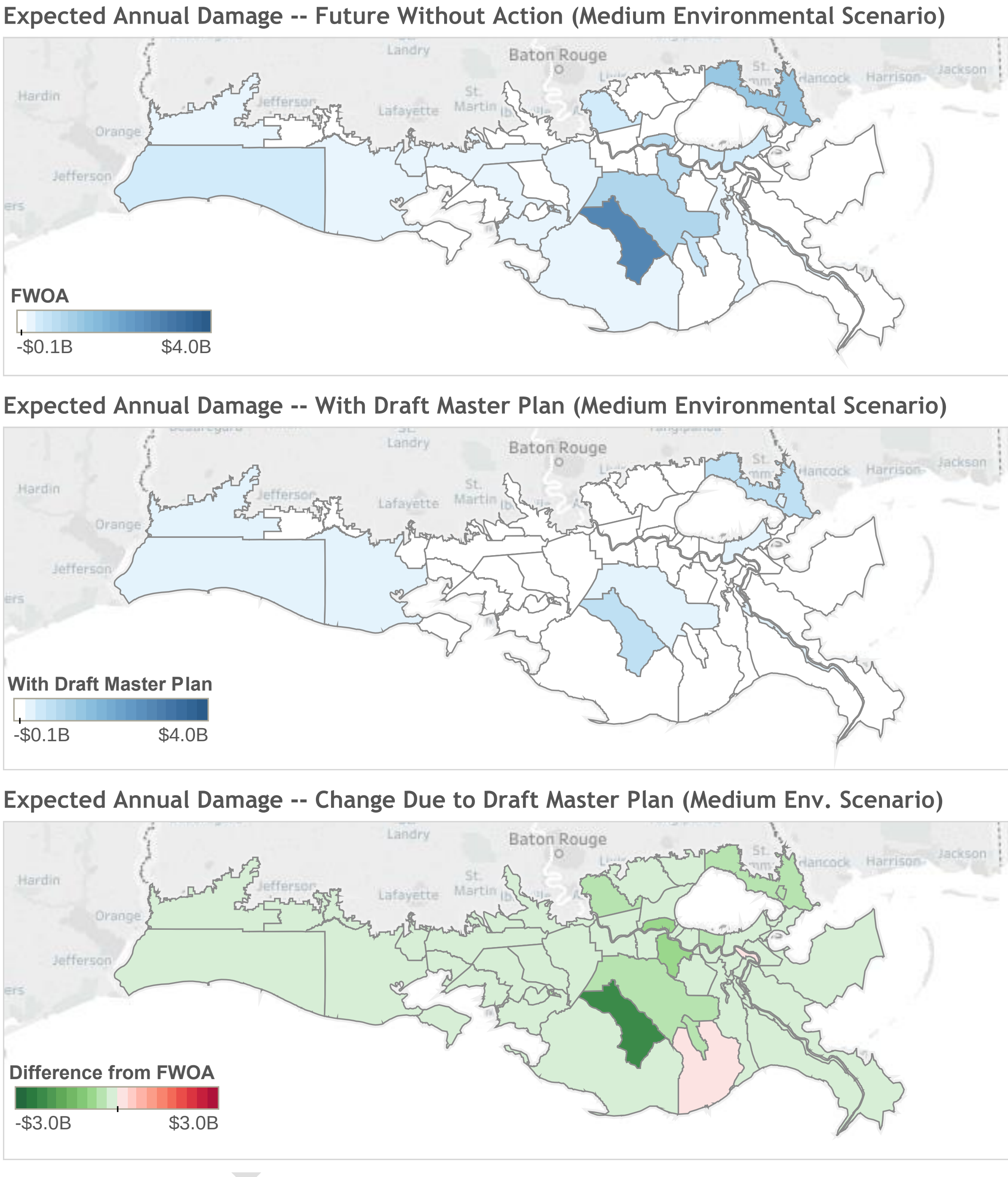


Figure 69: Patterns of EAD in Year 50 for the FWOA Condition (Top) and With the Draft Master Plan (Middle), and Change in EAD Due to the Draft Master Plan (bottom) for the Medium Environmental Scenario.

Figure 70 shows the spatial pattern of risk under the High environmental scenario for the FWOA condition (top), with the 2017 Draft Master Plan in place (middle), and the change in risk due to the 2017 Draft Master Plan (bottom). The 2017 Draft Master Plan reduces risk the most in the

Terrebonne – Houma risk area (from \$4.8 billion to \$1.8 billion). Other areas with high risk reduction include:

- St. John the Baptist – Laplace/Reserve (\$1.0 billion reduction)
- Lafourche – Raceland (\$900 million reduction)
- Jefferson – Kenner/Metairie (\$770 million reduction),
- St. Charles – Hahnville/Luling (\$750 million reduction)
- St. Tammany (\$640 million reduction)
- Ascension – Prairieville/Sorrento (\$640 million reduction)

Most other regions would realize risk reduction except for Terrebonne – Lower, Lafourche – Lower, Jefferson – Marrero/Gretna, Plaquemines – Belle Chasse, Orleans – Algiers, and St. Bernard.

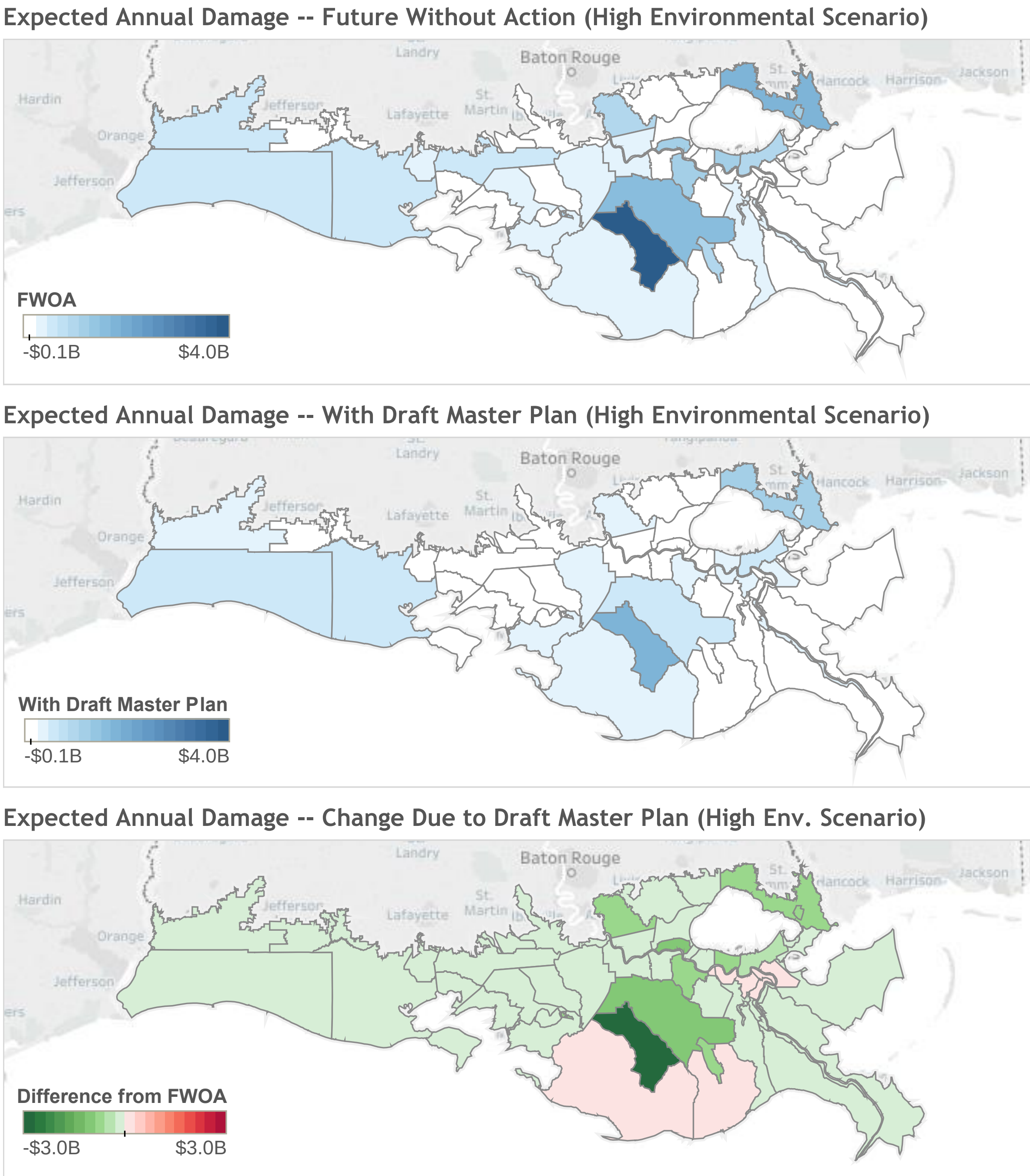


Figure 70: Patterns of EAD in Year 50 for the FWOA Condition (Top) and With the Draft Master Plan (Middle), and Change in EAD Due to the Draft Master Plan (bottom) for the High Environmental Scenario.

3.5.2 Draft Plan Restoration

3.5.2.1 Formulation

Prior to specifying the Restoration component of the draft plan alternative, the Planning Tool was used to formulate one more version of the Modified Maximize Land—called the Updated Modified Maximize Land alternative. This alternative reduced the total budget from $25B to $23.5B to allow funds to be set aside for the barrier island breach management program. This program was specified to be $1.5B, which was the approximate amount of Barrier Island projects selected for the Maximize Land, $25B, High Environmental Scenario alternative, and also is consistent with past and current CPRA investments in barrier island restoration (~$30M/year).

The Restoration component of the draft plan alternative was then based directly upon these results, with only a few minor changes to account for ongoing project planning and engineering/design:

- Moved Calcasieu Ship Channel Salinity Control Measures (004.HR.06) from Implementation Period 2 to Implementation Period 1.[17]
- Moved Golden Triangle Marsh Creation (001.MC.13) from Implementation Period 2 to Implementation 1.
- Moved West Rainey Marsh Creation (004.MC.07, increments 1 and 2) from Implementation Period 1 to Implementation Period 2 to compensate for the above adjustments.

3.5.2.2 Included Restoration Projects

Figure 71 shows the selection of Sediment Diversion projects for the Modified Maximize Land-v3, the Updated Modified Maximize Land, and draft plan alternatives. The only differences are the selection of the newer Mid-Breton Sound Diversion and Mid-Barataria Diversion projects (see Section 3.4.1 for more information on these new projects.)

[17] This constraint was inadvertently not included in the Updated Modified Maximize Land alternative.

Project	Modified Maximize Land-v3; High ES; $25B	Updated Modified Max Land; High ES; $23.5B	Draft Plan Restoration; High ES; $23.5B
03a.DI.01-0: Bayou Lafourche Diversion	●	●	●
03a.DI.05-0: Atchafalaya River Diversion	●	●	●
03b.DI.04-0: Increase Atchafalaya Flow to Terrebonne V3	●	●	●
001.DI.02-0: Lower Breton Diversion	●	●	●
001.DI.18-0: Central Wetlands Diversion	●	●	●
001.DI.21-0: East Maurepas Diversion V3	●	●	●
001.DI.100-0: Manchac Landbridge Diversion	●	●	●
001.DI.101-0: Ama Sediment Diversion	◆	◆	◆
001.DI.102-0: Union Freshwater Diversion V3	●	●	●
001.DI.23-0: Mid-Breton Sound Diversion	●		
001.DI.104-0: Mid-Breton Sound Diversion		●	●
002.DI.101-0: Mid-Barataria Diversion	●		
002.DI.102-0: Mid-Barataria Diversion		●	●

Implementation Period
● Years 1-10 ◆ Years 11-30

Figure 71: Selected Diversion Projects for Modified Maximize Land-v3, Updated Modified Maximize Land, and Draft Plan Restoration Alternatives.

Figures 72, 73, and 74 show the selected restoration projects, summary of selected project costs, and locations for the restoration projects.

Implementation Period 1 (yrs 1-10)

- 03a.HR.02: Central Terrebonne Hydrologic Restoration
- 001.HR.100: LaBranche Hydrologic Restoration
- 004.HR.06: Calcasieu Ship Channel Salinity Control Measures
- 03b.MC.07: East Rainey Marsh Creation
- 001.MC.05: New Orleans East Landbridge Restoration
- 001.MC.13: Golden Triangle Marsh Creation
- 001.MC.108: Guste Island Marsh Creation
- 004.MC.100: Freshwater Bayou North Marsh Creation
- 004.MC.101: Freshwater Bayou South Marsh Creation
- 03a.RC.04: Mauvais Bois Ridge Restoration
- 03a.RC.06: Bayou Pointe au Chene Ridge Restoration
- 001.RC.100: Bayou Terre aux Boeufs Ridge Restoration
- 001.RC.103: Carlisle Ridge Restoration
- 002.RC.101: Adams Bay Ridge Restoration
- 002.RC.102: Bayou Eau Noire Ridge Restoration
- 002.RC.103: Grand Bayou Ridge Restoration
- 03a.DI.01: Bayou Lafourche Diversion
- 03a.DI.05: Atchafalaya River Diversion
- 03b.DI.04: Increase Atchafalaya Flow to Terrebonne
- 001.DI.02: Lower Breton Diversion
- 001.DI.18: Central Wetlands Diversion
- 001.DI.21: East Maurepas Diversion
- 001.DI.100: Manchac Landbridge Diversion
- 001.DI.102: Union Freshwater Diversion
- 001.DI.104: Mid-Breton Sound Diversion
- 002.DI.102: Mid-Barataria Diversion
- 03b.SP.01: Freshwater Bayou Shoreline Protection (Belle Isle Canal to Lock)
- 001.SP.01: Manchac Landbridge Shoreline Protection
- 001.SP.101: Unknown Pass to Rigolets Shoreline Protection
- 001.SP.104: LaBranche Wetlands Shoreline Protection
- 002.SP.100: Lake Hermitage Shoreline Protection
- 002.SP.102: East Snail Bay Shoreline Protection
- 002.SP.106: Bayou Perot Shoreline Protection
- 004.SP.03: Freshwater Bayou Canal Shoreline Protection

Implementation Period 2 (yrs 11-30)

- 03a.HR.100: Grand Bayou Hydrologic Restoration
- 03a.MC.07: Belle Pass-Golden Meadow Marsh Creation
- 03a.MC.09b: North Terrebonne Bay Marsh Creation - Component B
- 03a.MC.100: South Terrebonne Marsh Creation
- 03a.MC.101: North Lake Mechant Marsh Creation
- 03b.MC.03: Marsh Island Marsh Creation
- 03b.MC.101: Southeast Marsh Island Marsh Creation
- 001.MC.05: New Orleans East Landbridge Restoration
- 001.MC.06a: Breton Marsh Creation - Component A
- 001.MC.07a: Lake Borgne Marsh Creation - Component A
- 001.MC.08a: Central Wetlands Marsh Creation - Component A
- 001.MC.102: Pointe a la Hache Marsh Creation
- 001.MC.104: East Bank Land Bridge Marsh Creation
- 001.MC.105: Spanish Lake Marsh Creation
- 001.MC.106: St. Tammany Marsh Creation
- 001.MC.107: Tiger Ridge/Maple Knoll Marsh Creation
- 002.MC.05e: Large-Scale Barataria Marsh Creation - Component E
- 004.MC.01: South Grand Chenier Marsh Creation
- 004.MC.04: Mud Lake Marsh Creation
- 004.MC.07: West Rainey Marsh Creation
- 004.MC.10: Southeast Calcasieu Lake Marsh Creation
- 004.MC.13: Cameron Meadows Marsh Creation
- 004.MC.16: East Pecan Island Marsh Creation
- 004.MC.23: Calcasieu Ship Channel Marsh Creation
- 004.MC.102: White Lake Marsh Creation
- 004.MC.107: West Sabine Refuge Marsh Creation
- 03a.RC.02: Bayou DuLarge Ridge Restoration
- 03a.RC.05: Bayou Terrebonne Ridge Restoration
- 001.RC.01: Bayou LaLoutre Ridge Restoration
- 002.RC.02: Spanish Pass Ridge Restoration
- 002.RC.100: Red Pass Ridge Restoration
- 001.DI.101: Ama Sediment Diversion
- 03a.SP.100: North Lake Boudreaux Shoreline Protection
- 002.SP.103: West Snail Bay Shoreline Protection

Implementation Period 3 (yrs 31-50)

- 03b.MC.09: Point Au Fer Island Marsh Creation
- 001.MC.101: Uhlan Bay Marsh Creation
- 001.MC.102: Pointe a la Hache Marsh Creation
- 002.MC.04a: Lower Barataria Marsh Creation - Component A
- 004.MC.19: East Calcasieu Lake Marsh Creation
- 004.MC.103: Little Chenier Marsh Creation
- 004.MC.104: Calcasieu Lake West Bank Marsh Creation
- 004.MC.105: West Brown Lake Marsh Creation
- 004.MC.107: West Sabine Refuge Marsh Creation
- 004.RC.02: Cheniere au Tigre Ridge Restoration
- 004.RC.03: Pecan Island Ridge Restoration

Type

- Hydrologic Restoration
- Marsh Creation
- Ridge Restoration
- Sediment Diversion
- Shoreline Protection

Figure 72: Selected Projects by Type (Color) and Implementation Period (Column) for the Draft Plan Alternative.

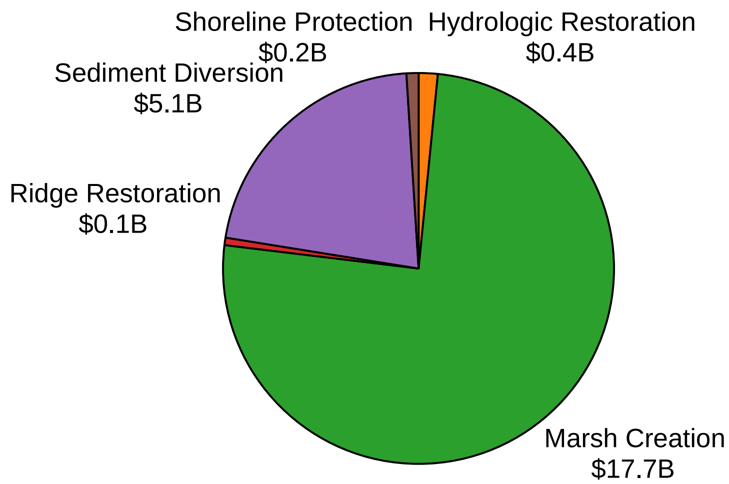


Figure 73: Summary of Costs of Selected Projects by Type for the Draft Plan Alternative.

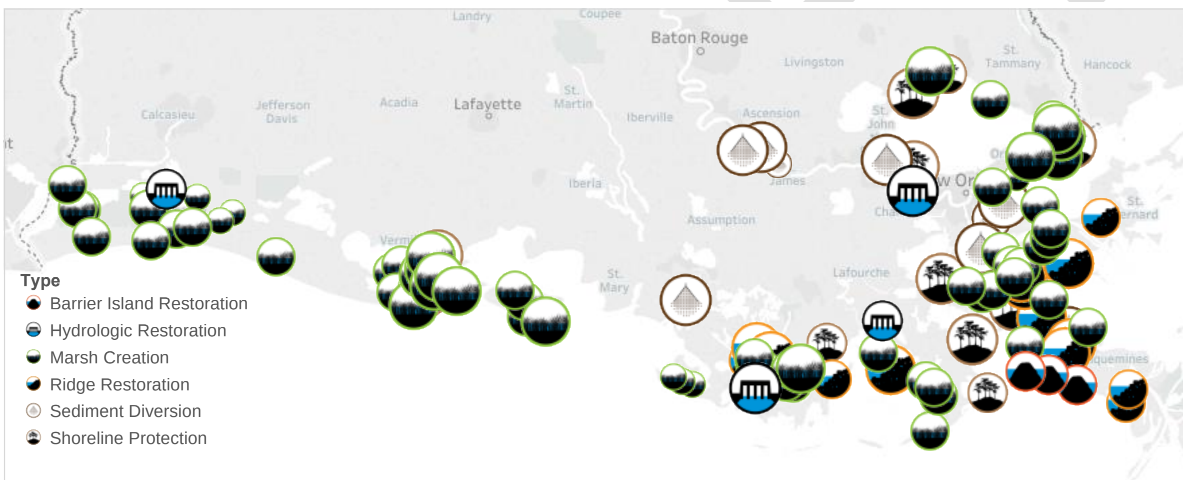


Figure 74: Locations of Restoration Projects Specified for the Draft Plan Alternative.

3.5.2.3 Draft Plan Restoration Outcomes

The ICM was used to model the outcomes of the 2017 Draft Master Plan alternative. Figure 75 shows coast wide land area over time and change from the FWOA condition for the draft master plan under the Medium and High environmental scenarios. The colors refer to the 11 ecoregions. The top graphs show that the draft master plan builds significant land, as compared to the FWOA condition, with year 50 land being lower in the High environmental scenario than the Medium environmental scenario. The bottom graphs show that change in land is greatest under the High environmental scenario and in the Upper Pontchartrain, Upper Barataria, and Breton ecoregions.

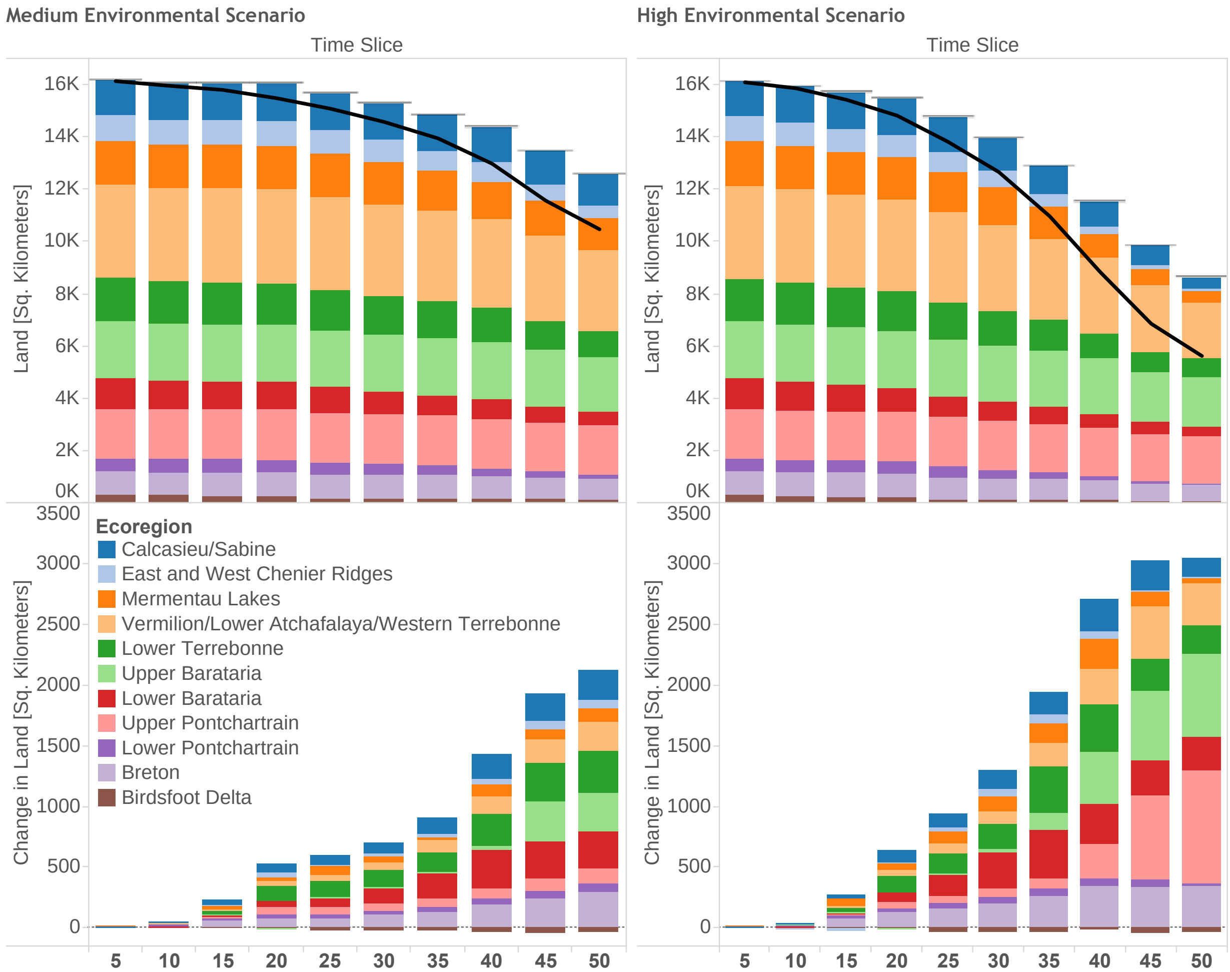


Figure 75: Land Outcomes (Bars) and Future Without Action (Black Line) Over Time by Ecoregion for Draft Master Plan Under Medium Environmental Scenario (Left) and High Environmental Scenario (Right).

Figure 76 summarizes ecosystem metric outcomes from the ICM under FWOA conditions, with the draft master plan, and changes from FWOA conditions for different time slices. The right column is color coded to indicate positive or negative changes in outcomes relative to the FWOA condition. Cells colored green for the percent change from FWOA indicate metrics that benefit from the draft master plan. Similarly cells colored red are metrics that are negatively impacted by the draft master plan. The draft master plan improves outcomes by year 50 for the following metrics:

- Wild Crawfish Habitat
- Largemouth Bass Habitat
- Alligator Habitat
- Mottled Duck Habitat.

For the other metrics, the draft master plan reduces outcomes, but generally no more than 12 percent, except for Brown Pelican Habitat, which is reduced by about 32 percent.

Ecosystem Metric Outcomes -- High Environmental Scenario

Metric	Units	Time Slice	FWOA	With Draft Master Plan	Change from FWOA	Percent Change from FWOA
Land Area	Sq. Km.	20	14,810	15,434	625	4.2%
		50	5,618	8,618	3,000	53.4%
Oyster Habitat	HUs	20	14,394	10,696	-3,698	-25.7%
		50	21,323	21,412	89	0.4%
Blue Crab Habitat	HUs	20	74,721	74,539	-182	-0.2%
		50	63,676	63,452	-223	-0.4%
Large Juvenile Brown Shrimp Habitat	HUs	20	78,057	71,264	-6,794	-8.7%
		50	109,847	96,797	-13,050	-11.9%
Small Juvenile Brown Shrimp Habitat	HUs	20	63,766	58,196	-5,571	-8.7%
		50	69,788	64,154	-5,633	-8.1%
Small Juvenile White Shrimp Habitat	HUs	20	58,198	54,951	-3,247	-5.6%
		50	64,706	60,869	-3,837	-5.9%
Wild Crawfish Habitat	HUs	20	862	828	-34	-4.0%
		50	108	148	40	36.7%
Adult Bay Anchovy Habitat	HUs	20	90,253	83,971	-6,282	-7.0%
		50	121,860	108,324	-13,535	-11.1%
Adult Gulf Menhaden Habitat	HUs	20	70,327	66,126	-4,201	-6.0%
		50	94,761	83,731	-11,030	-11.6%
Juvenile Gulf Menhaden Habitat	HUs	20	81,393	81,089	-304	-0.4%
		50	74,066	73,371	-696	-0.9%
Adult Spotted Seatrout Habitat	HUs	20	76,345	71,873	-4,472	-5.9%
		50	96,168	86,020	-10,148	-10.6%
Juvenile Spotted Seatrout Habitat	HUs	20	94,055	90,939	-3,116	-3.3%
		50	95,286	88,401	-6,885	-7.2%
Largemouth Bass Habitat	HUs	20	34,787	36,976	2,189	6.3%
		50	18,310	21,595	3,285	17.9%
Alligator Habitat	HUs	20	20,037	19,576	-461	-2.3%
		50	6,567	9,131	2,564	39.1%
Brown Pelican Habitat	HUs	20	511	417	-93	-18.2%
		50	172	116	-56	-32.5%
Gadwall Habitat	HUs	20	11,533	11,591	58	0.5%
		50	11,814	12,117	303	2.6%
Green Teal Habitat	HUs	20	26,606	26,203	-403	-1.5%
		50	20,164	21,604	1,439	7.1%
Mottled Duck Habitat	HUs	20	35,811	36,799	988	2.8%
		50	19,972	26,863	6,891	34.5%

Figure 76: Select ICM Ecosystem Metric Outcomes for FWOA, With Draft Master Plan, and Changes from FWOA Conditions Under the High Environmental Scenario (Right).

The 2017 Draft Master Plan also has a large impact on ecosystem metrics calculated by the EwE model. Figure 77 lists select metrics pertaining to adult and juvenile aquatic species. The right column shows the percent change with the 2017 Draft Master Plan relative to the FWOA conditions. The 2017 Draft Master Plan increases biomass for most species, in particular Juvenile Gulf Menhaden, and Adult and Juvenile Largemouth Bass. Only Juvenile Bay Anchovy is estimated to be negatively impacted in year 50 by the draft master plan, and only by about 6 percent.

Additional Ecosystem Metric Outcomes -- High Environmental Scenario

Metric	Units	Time Slice	FWOA	With Draft Master Plan	Change from FWOA	Percent Change from FWOA
Adult Bay Anchovy	tonnes/sq. km	20	0.46	0.52	0.07	14.5%
		50	0.25	0.32	0.07	25.9%
Juvenile Bay Anchovy	tonnes/sq. km	20	0.46	0.54	0.09	19.1%
		50	0.23	0.22	-0.01	-6.1%
Adult Blue Crab	tonnes/sq. km	20	2.17	2.34	0.17	7.7%
		50	1.41	1.75	0.34	24.5%
Juvenile Blue Crab	tonnes/sq. km	20	2.51	2.71	0.20	7.8%
		50	1.67	1.88	0.21	12.6%
Adult Brown Shrimp	tonnes/sq. km	20	11.09	11.45	0.36	3.3%
		50	11.55	12.27	0.72	6.2%
Juvenile Brown Shrimp	tonnes/sq. km	20	0.24	0.25	0.01	3.5%
		50	0.24	0.25	0.01	5.3%
Adult Gulf Menhaden	tonnes/sq. km	20	1.56	1.33	-0.24	-15.1%
		50	1.39	1.43	0.04	3.0%
Juvenile Gulf Menhaden	tonnes/sq. km	20	0.50	0.60	0.10	20.6%
		50	0.19	0.30	0.11	58.6%
Adult Largemouth Bass	tonnes/sq. km	20	0.59	0.93	0.33	56.4%
		50	0.29	0.81	0.53	181.6%
Juvenile Largemouth Bass	tonnes/sq. km	20	0.02	0.04	0.01	60.2%
		50	0.02	0.03	0.01	62.7%
Adult Oyster	tonnes/sq. km	20	0.61	0.69	0.08	13.1%
		50	0.67	0.86	0.19	27.7%
Oyster Spat	tonnes/sq. km	20	0.01	0.01	0.00	13.9%
		50	0.01	0.02	0.00	30.6%
Adult Spotted Seatrout	tonnes/sq. km	20	0.00	0.01	0.00	5.7%
		50	0.00	0.00	0.00	8.4%
Juvenile Spotted Seatrout	tonnes/sq. km	20	0.00	0.00	0.00	5.9%
		50	0.00	0.00	0.00	10.4%
Adult White Shrimp	tonnes/sq. km	20	5.93	6.10	0.17	2.8%
		50	5.51	6.07	0.57	10.3%
Juvenile White Shrimp	tonnes/sq. km	20	0.14	0.14	0.00	3.2%
		50	0.12	0.13	0.01	10.5%

Figure 77: Additional Ecosystem Metric Outcomes for FWOA, With Draft Master Plan, and Changes FWOA Conditions Under the High Environmental Scenario (Right).

4.0 Conclusions

4.1 Summary

Coastal Louisiana continues to face significant challenges of coastal land loss and accompanying impacts on ecosystem services, as well as high risk to flooding from storm surges. The 2017 Coastal Master Plan builds on the 2012 Coastal Master Plan by defining 50-years of risk reduction and restoration investments to build land and reduce flood risk. CPRA again used an objective, science based planning framework and Planning Tool to compare hundreds of different projects and assemble different alternatives for consideration by CPRA planners and management and its stakeholders.

For the 2017 Coastal Master Plan, the Planning Tool evaluated newly modeled projects and evaluated them with respect to new estimates of FWOA conditions under a set of environmental scenarios. As in 2012, the Planning Tool helped CPRA compare individual projects and develop alternatives of projects under different budgets, scenario conditions, and other constraints.

The Planning Tool team and CPRA evaluated about 200 alternatives using tens of different interactive visualizations. Many of these alternatives and visualizations were used to support discussions with the Framework Development Team and other stakeholders. CPRA used the Planning Tool to help reconfirm the most appropriate total budget—$50 billion—and environmental scenario to base project selection on—the High environmental scenario. The Planning Tool was also used to define a new set of nonstructural projects for consideration. Several rounds of alternative formulation helped CPRA to ultimately define the draft master plan.

The Planning Tool and the master plan are supporting an adaptive planning process. The 2012 Coastal Master Plan defined an initial list of projects to be implemented over the next 50 years. Recognizing that the plan, as with all long-term plans, was made without perfect information or foresight, CPRA began implementing parts of the plan while continuing to invest in new data, models, and tools. New project ideas were also considered.

Due to the improvements in data and tools, the projects included in the 2017 Draft Coastal Master Plan differ from those in the 2012 Coastal Master Plan. These adjustments, however, represent progress in an adaptive planning process. The 2017 Coastal Master Plan analysis better reflects the coastal processes and current understanding of how conditions could change in the coming 50 years. The 2017 Coastal Master Plan will therefore provide an improved roadmap for Louisiana to follow—until its next update in 2022.

4.2 Key Limitations

The 2017 planning framework and Planning Tool are conceptually the same as those used for the 2012 Master Plan, and the previous limitations still could apply. One major limitation is that the models are only able to evaluate the risk effects of individual risk reduction projects and the land and ecosystem effects of individual restoration projects. As such, the Planning Tool must define alternatives initially without information about project interactions. Iteration between developing and evaluating alternatives is the primary way to overcome this limitation. The 2017 process has improved upon 2012 by including multiple iterations in the planning process. Up to the development of the 2017 Draft Master Plan, one complete iteration was performed. CPRA is currently evaluating the recent findings from modeling the draft master plan, which may lead to additional insights into how best to adjust the Planning Tool's formulation process for the final master plan.

4.3 Using the Planning Tool to Define a Robust, Adaptive Plan

After completion of the 2017 Coastal Master Plan, CPRA may choose to continue to use the Planning Tool to refine the master plan to be robust and adaptive. A robust, adaptive plan is one that is designed to perform well across many plausible futures, and accomplishes this by defining different decision pathways, which specify how the plan's implementation would change – or adapt – depending on how the future unfolds.

The goal would be to identify near-term investments for the first implementation period that are estimated to perform reasonably well regardless of how the future unfolds. When the second implementation period begins in 10 years, the time horizon for anticipating the future would be shorter, and CPRA's understanding of how the coast is evolving would likely be improved. CPRA would then be in a better position to determine which projects to implement in the 2nd and 3rd periods.

The Planning Tool could use this approach by implementing these steps:

1. Develop an alternative for each scenario: the projects selected would be those that would maximize CPRA objectives for each scenario.
2. Identify a set of projects to implement in period 1, based on which projects are selected for implementation in the first period across most or all evaluated scenarios. These are called the period 1 low regret projects and represent choices that would be acceptable despite the uncertainty about the future.
3. Develop another set of alternatives for each scenario, this time fixing the period 1 low regret projects. These alternatives would define those projects to be implemented in periods 2 and 3 that would perform the best across scenarios.

With this approach, CPRA is able to defer the choice of scenario that it must plan for until the second implementation period. Figure 78 shows an illustration of such a robust, adaptive plan. Alternatively, CPRA could repeat the process in 10 years and implement only those projects in implementation period 2 that are shown at that time to be low-regret across the scenarios.

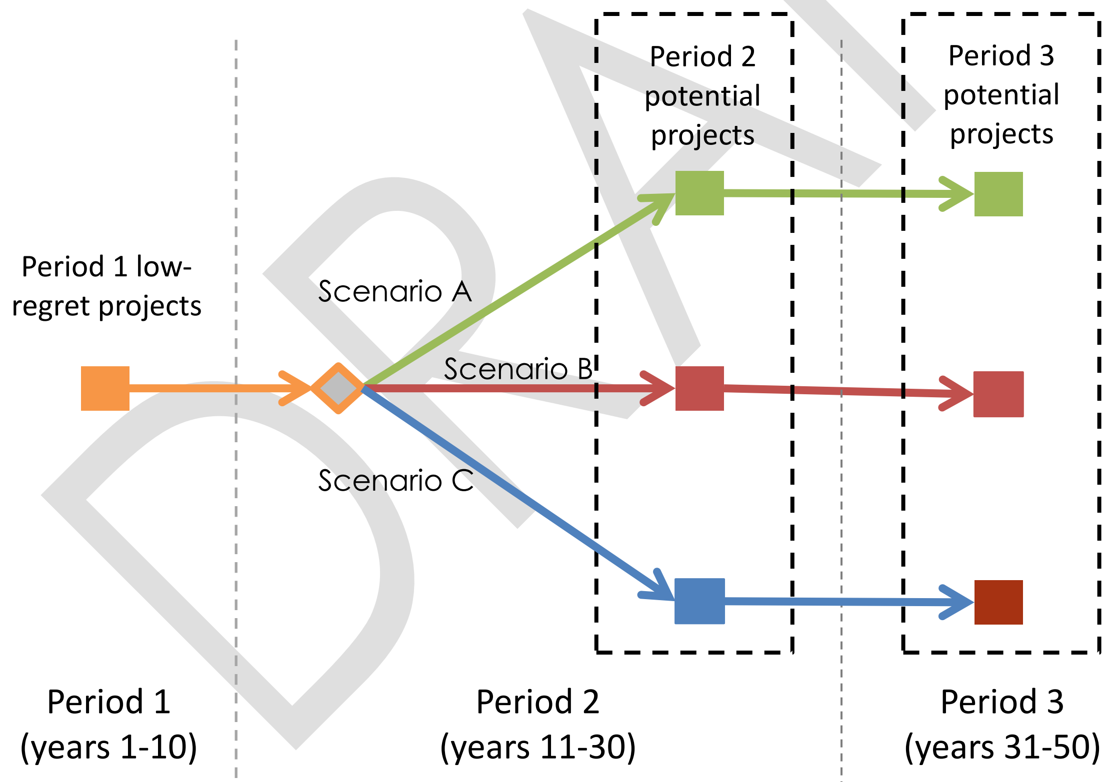


Figure 78: Illustration of a Robust, Adaptive Master Plan.

A robust, adaptive plan may not perform as well in any given scenario as an alternative that is optimized for that specific scenario, but it is likely to perform better across the scenarios than a single, static alternative would. The Planning Tool could test the tradeoff between robustness and optimality by simply comparing the performance of the step 1 alternatives (which are optimized for each scenario) to the performance of the robust, adaptive strategy. CPRA could then decide whether to adopt this approach going forward.

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Appendix A: Planning Tool Data Assimilation Scripts

The GAMS optimization model and Tableau visualization tool are supported on the backend by a single SQLite database that holds projects attribute and effects information. This information is derived from a variety of sources and modeling teams (Table 14). Because the data for any given project is derived from multiple sources, a set of R scripts is used to process and merge the data into a single database.

Table 14: Sources of Data for the Planning Tool.

Data	Source	Description
Borrow sources	Arcadis	GIS Shapefile. Amount of sediment available for diversion projects.
Project risk effects	CLARA modeling team	CSV files. Structural and non-structural risk project effects. Includes FWOA.
Project metrics and restoration effects	The Water Institute of the Gulf	CSV files. Project metrics and restoration effects derived from the ICM model. Includes FWOA.
Project attributes	Arcadis.	CSV files. Project cost and sediment requirement (diversion projects). Data varies by implementation period.
Shapefiles	CLARA modeling team	GIS Shapefiles. Various polygons used in the visualization tool.

During the merge process a unique identifiers is appended to the data to keep track of each type of data and allow for multiple versions of the same data elements to be included in the data base. In addition we created a Planning Tool Analysis ID to help us distinguish data derived from new or updated models from the modeling teams, see Table 15.

Table 15: Planning Tool Analysis Identifiers.

Planning Tool Analysis ID	Description
2	Master Plan 2017
3	Data derived from version 3 of the ICM model
4	Alternative-level effects and attributes